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**Ohara et al.**

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(45) **Date of Patent:** **Dec. 1, 2015**

(54) **EVALUATION METHOD, EVALUATION APPARATUS, COMPUTER READABLE RECORDING MEDIUM HAVING STORED THEREIN EVALUATION PROGRAM**

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(30) **Foreign Application Priority Data**

Feb. 3, 2012 (JP) ..... 2012-021980

(51) **Int. Cl.**

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**G03B 43/00** (2006.01)  
**G02B 27/64** (2006.01)  
**G01M 7/02** (2006.01)  
**H04N 17/00** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H04N 5/23248** (2013.01); **G01M 7/02** (2013.01); **G02B 27/646** (2013.01); **G03B 43/00** (2013.01); **H04N 17/002** (2013.01); **G03B 2205/0007** (2013.01); **G03B 2217/005** (2013.01)

(58) **Field of Classification Search**

CPC ..... H04N 5/23248–5/23287; H04N 17/002; G01M 7/00–7/08; G03B 2205/0007–2205/0038; G03B 43/00; G02B 27/64; G02B 27/646

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,623,705 A \* 4/1997 Ohishi ..... G03B 5/00 348/E5.046  
2008/0291286 A1 11/2008 Fujiyama et al.

(Continued)

FOREIGN PATENT DOCUMENTS

JP 09-261526 A 10/1997  
JP 2006-101447 A 4/2006

(Continued)

OTHER PUBLICATIONS

International Search Report for corresponding International Application No. PCT/JP2013/000579 dated Mar. 5, 2013.

(Continued)

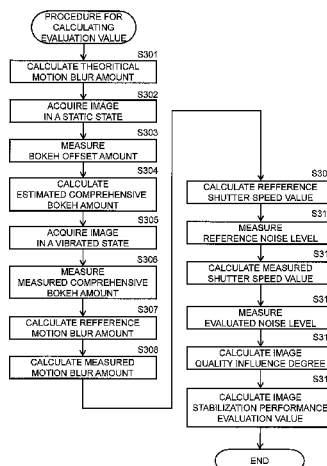
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(57) **ABSTRACT**

An evaluation method for evaluating the performance of an image stabilization function of an imaging apparatus includes: a first imaging step of imaging an object, with the image stabilization function being ON and the imaging apparatus being vibrated; a second imaging step of imaging the object, with the imaging apparatus being static; a first calculation step of calculating a first shutter speed based on the image taken in the first imaging step, and calculating a first evaluation value based on the first shutter speed and a reference shutter speed; a second calculation step of calculating a second evaluation value based on the images taken in the first and second imaging steps; and an evaluation step of calculating an evaluation value of the performance of the image stabilization function of the imaging apparatus, based on a result of subtraction of the second evaluation value from the first evaluation value.

**6 Claims, 26 Drawing Sheets**



(56)

**References Cited**

U.S. PATENT DOCUMENTS

2009/0179995 A1 7/2009 Fukumoto et al.  
 2011/0181741 A1\* 7/2011 Luneau ..... G01M 7/022  
 348/208.4

FOREIGN PATENT DOCUMENTS

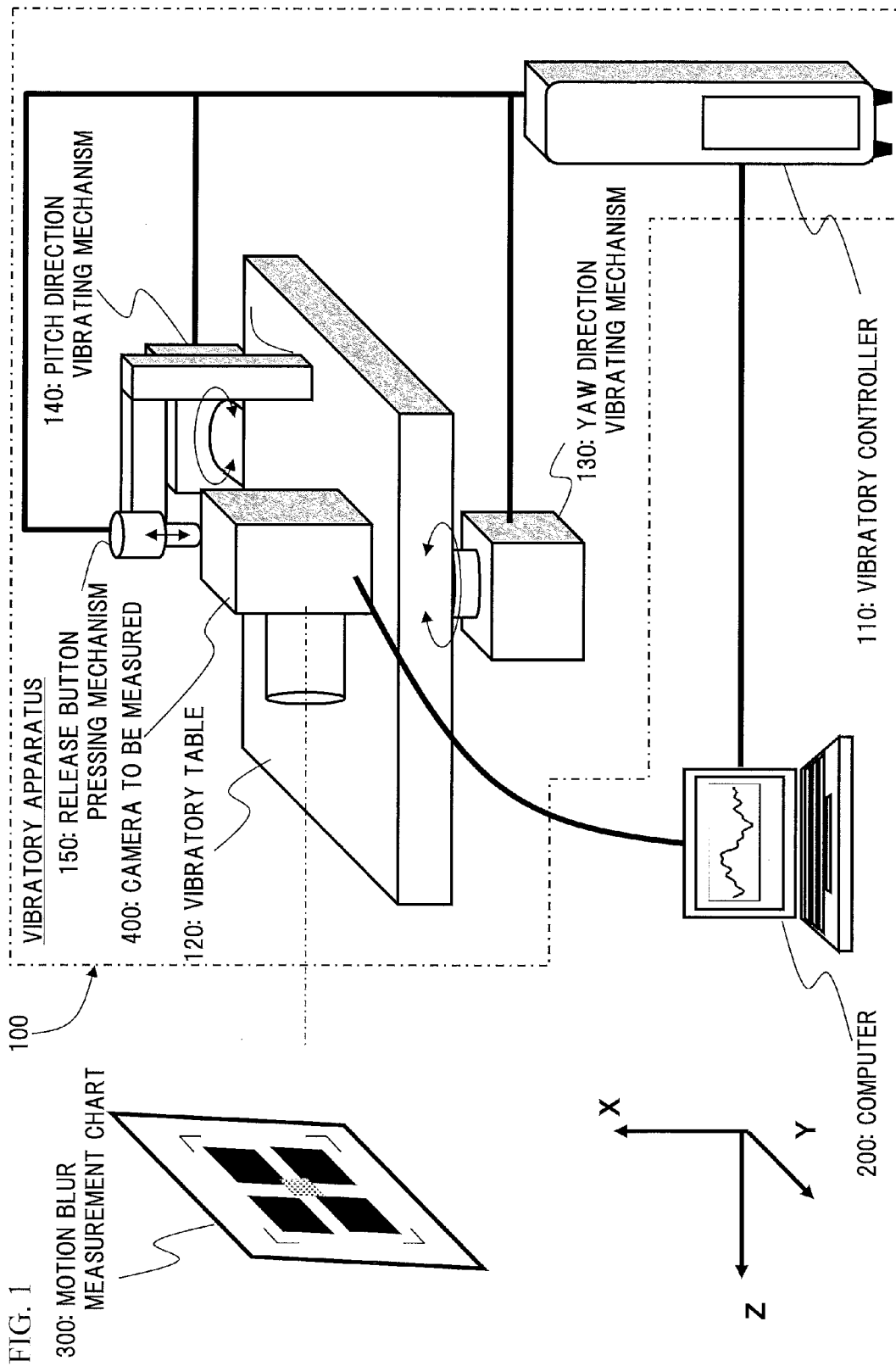
JP 2008-252228 A 10/2008  
 JP 2008-289122 A 11/2008

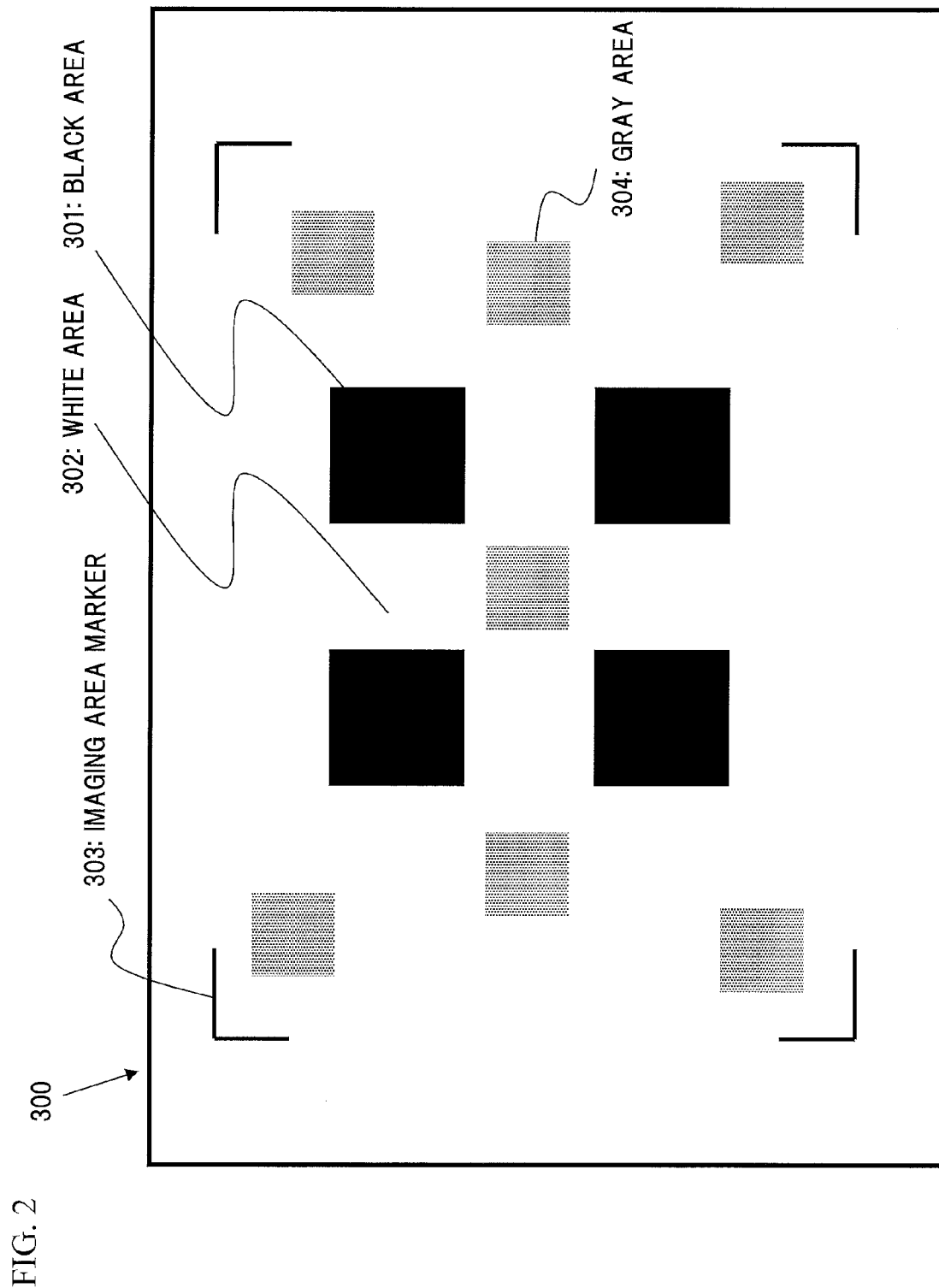
JP 2009-063827 A 3/2009  
 JP 2009-207118 A 9/2009  
 JP 2009-211023 A 9/2009  
 JP 2011-135524 A 7/2011  
 JP 2011-164413 A 8/2011  
 JP 2013-025267 A 2/2013

OTHER PUBLICATIONS

Form PCT/ISA/237 for corresponding International Application No.  
 PCT/JP2013/000579, dated Mar. 5, 2013.

\* cited by examiner





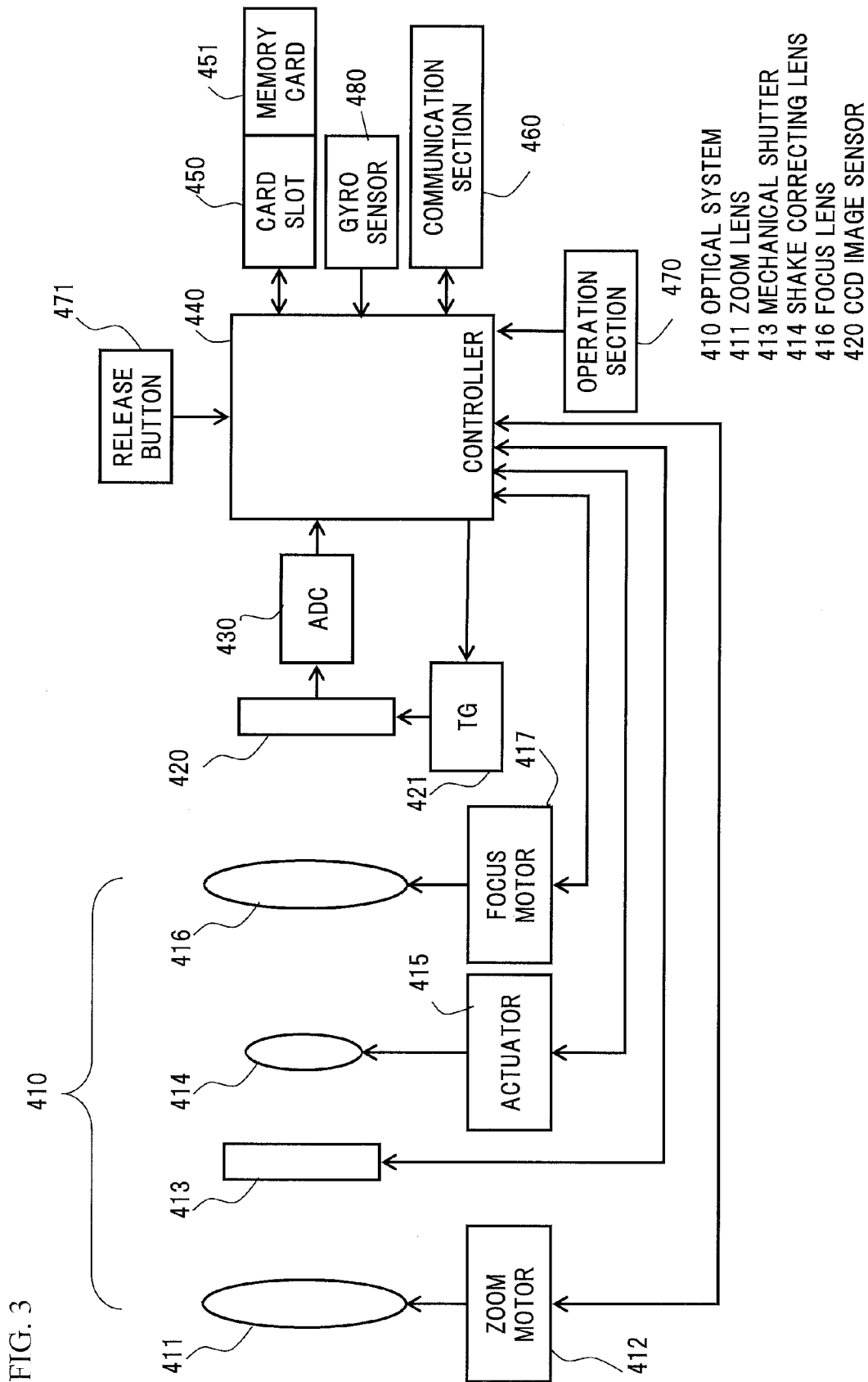


FIG. 4

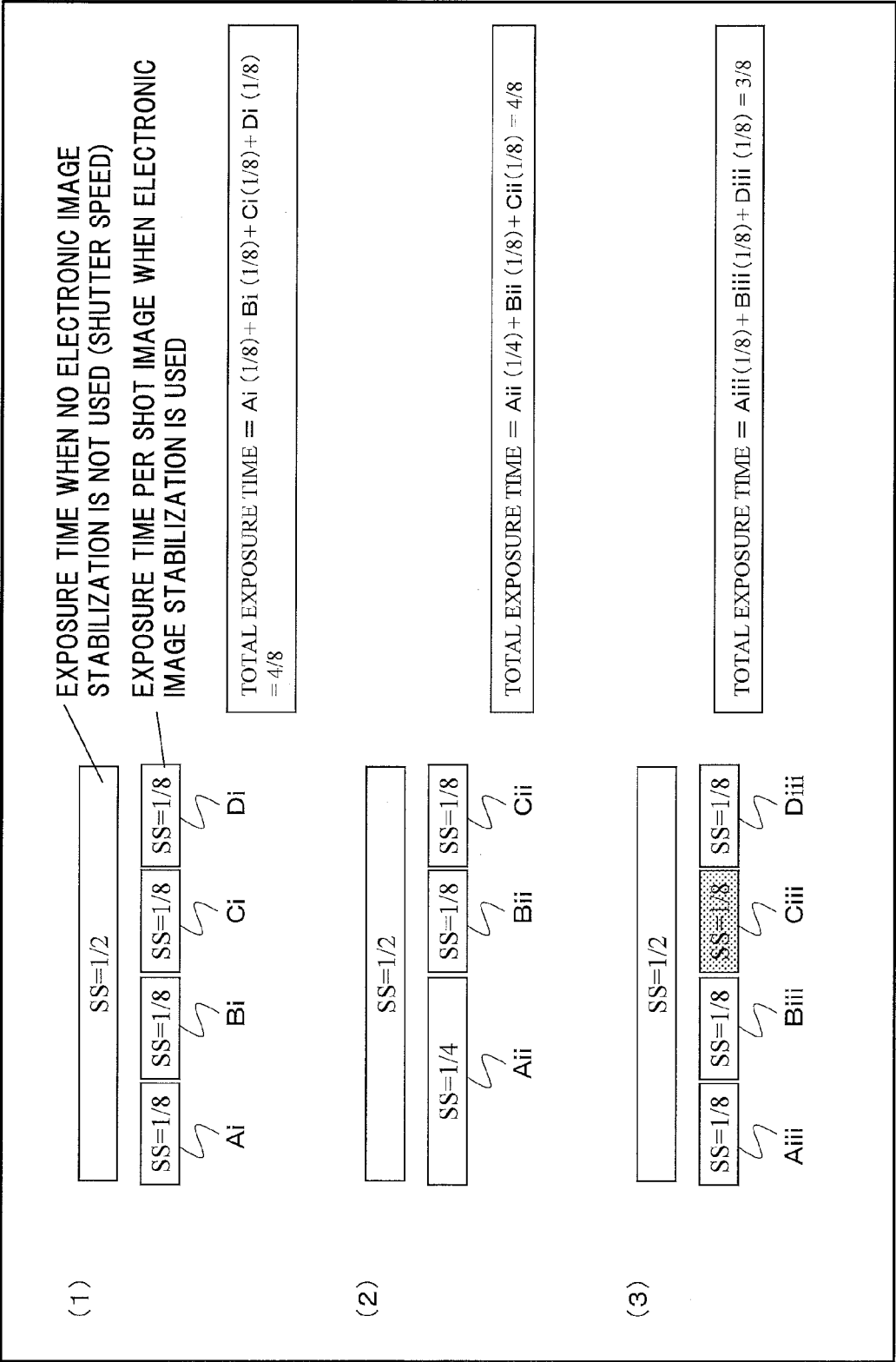
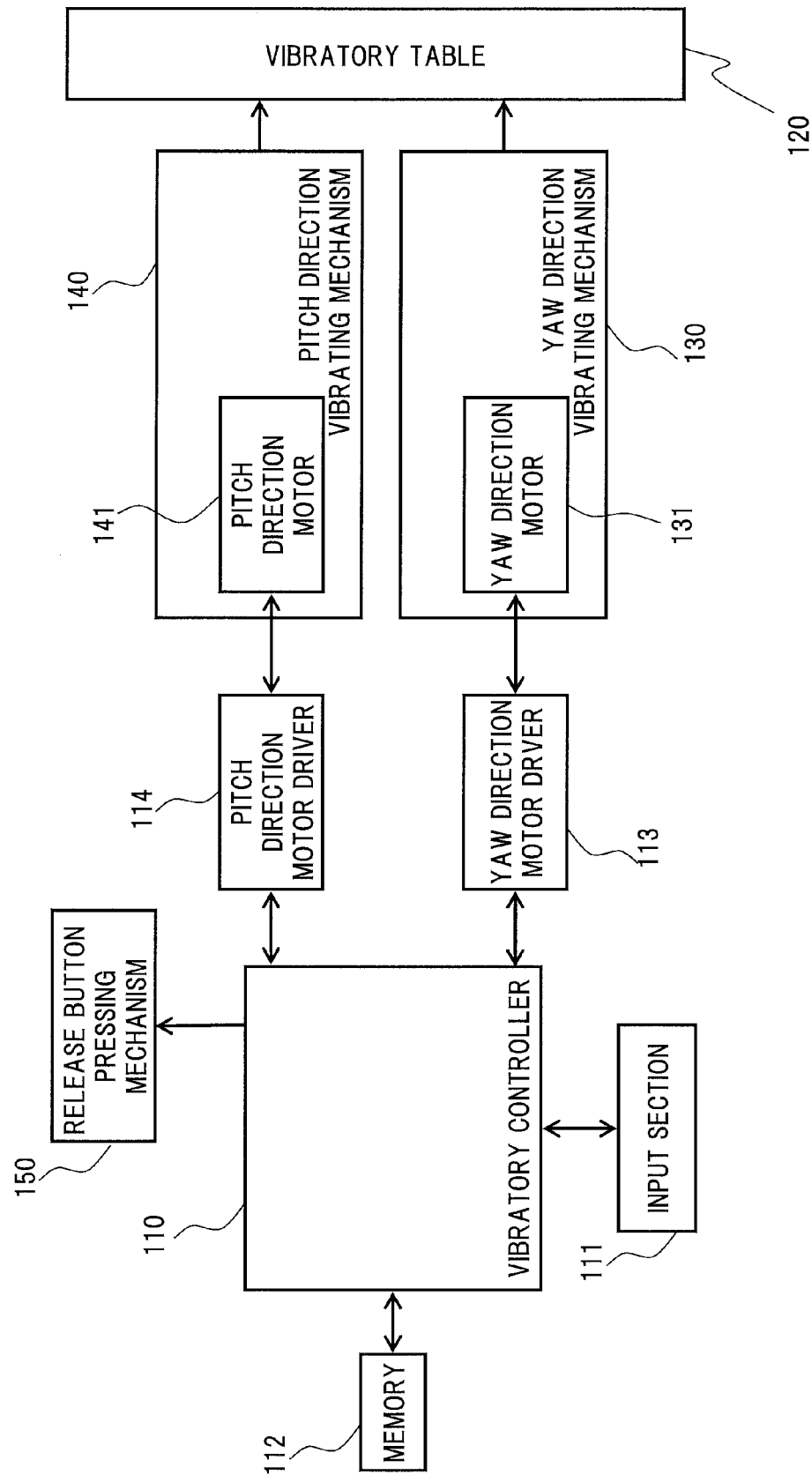


FIG. 5



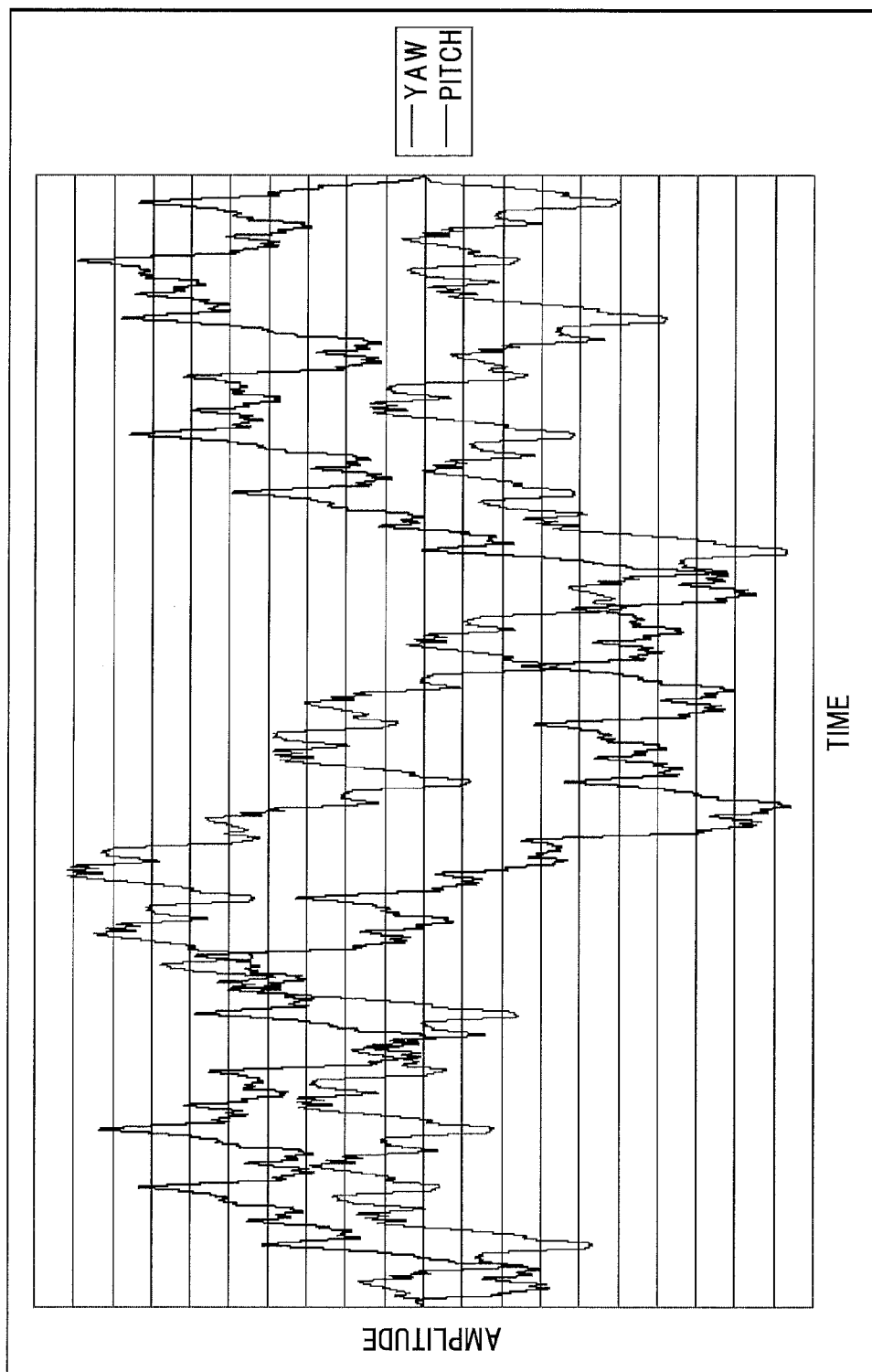


FIG. 6

FIG. 7

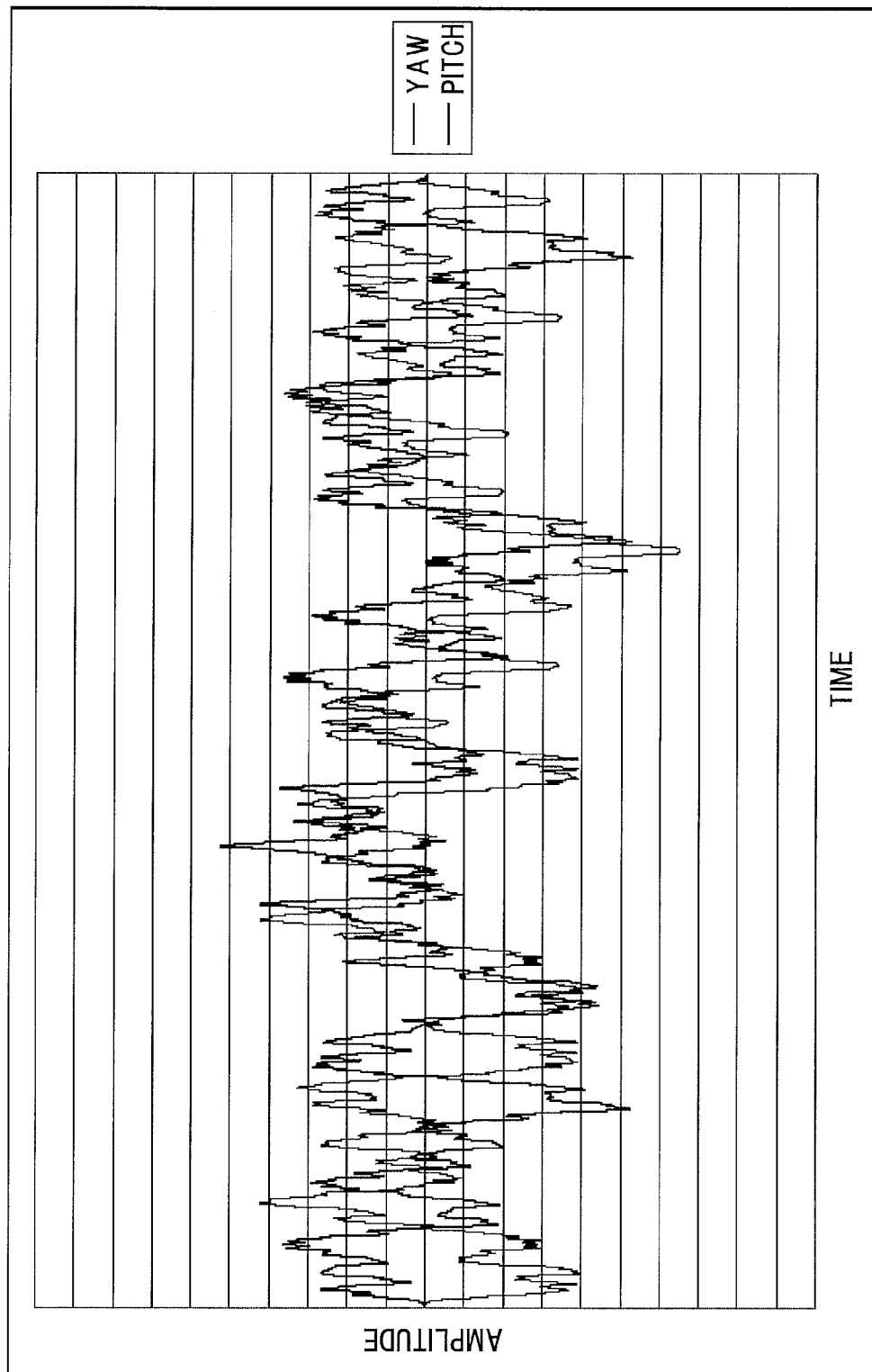


FIG. 8

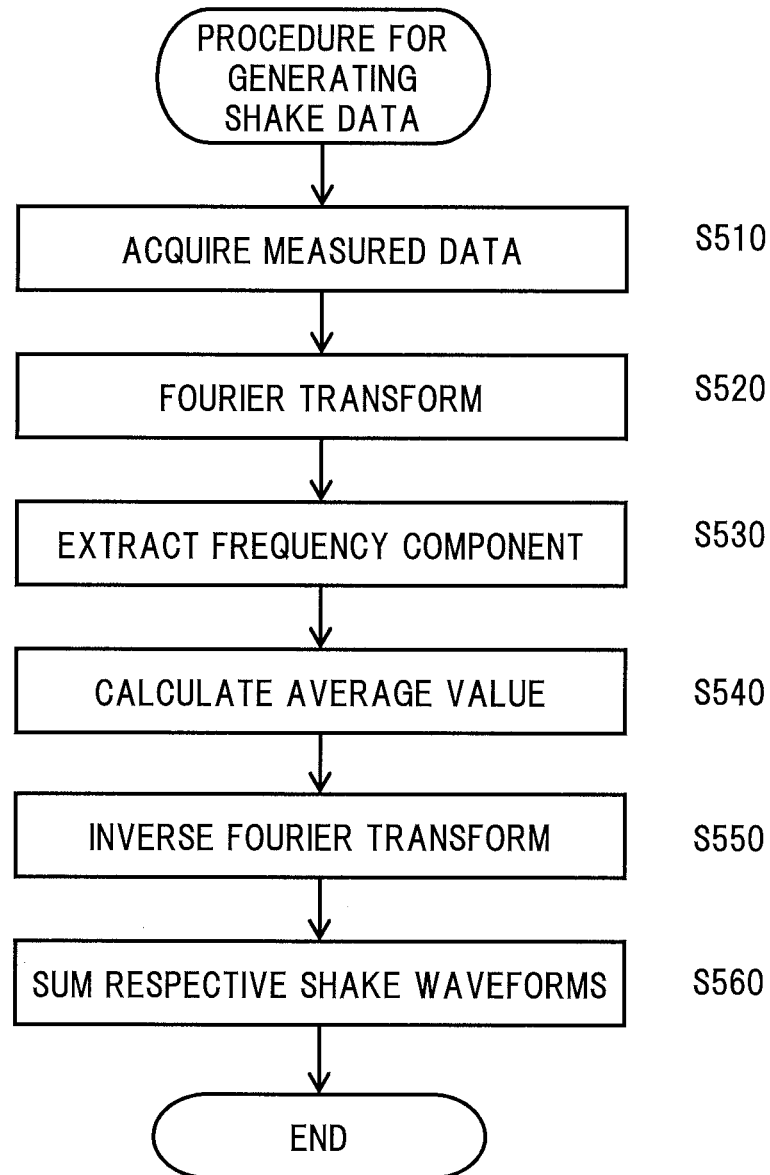


FIG. 9

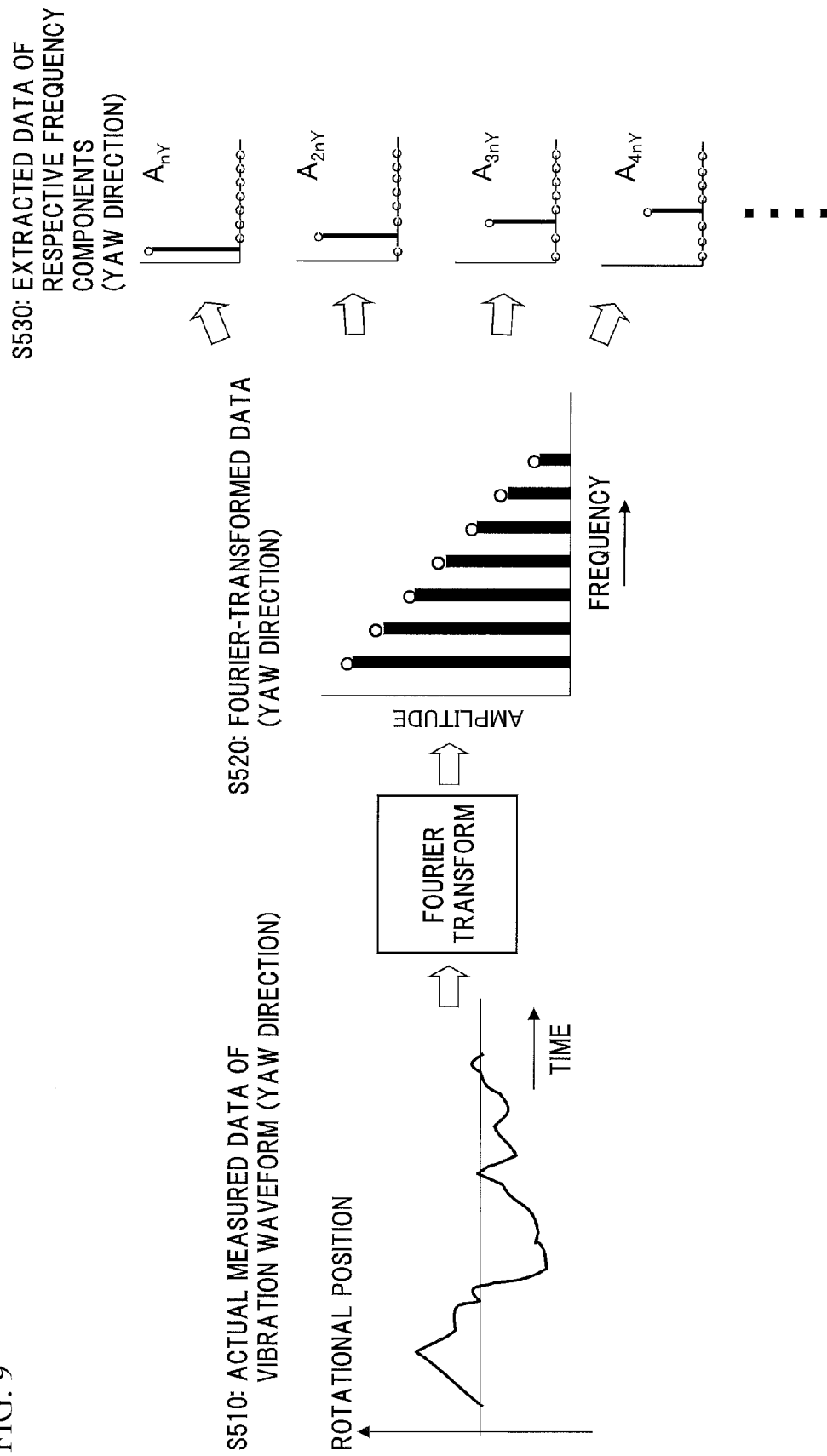
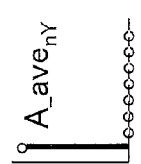
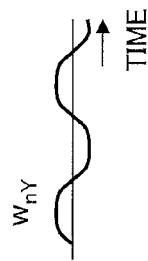


FIG. 10

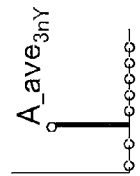
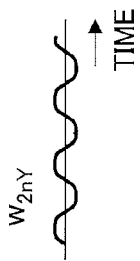
S540: AVERAGE VALUES OF EXTRACTED DATA OF RESPECTIVE FREQUENCY COMPONENTS



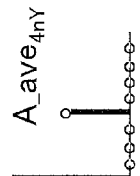
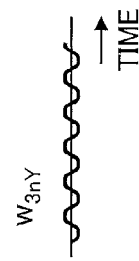
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TRANSFORM



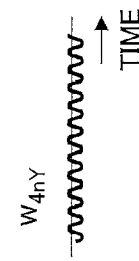
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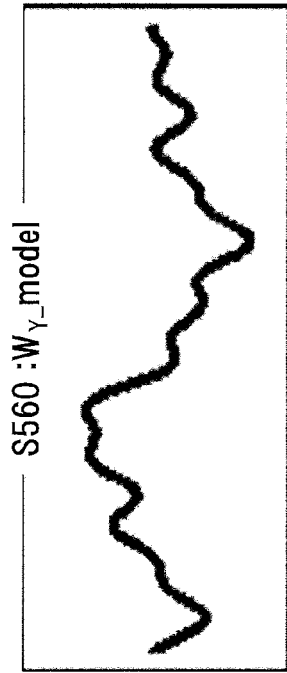
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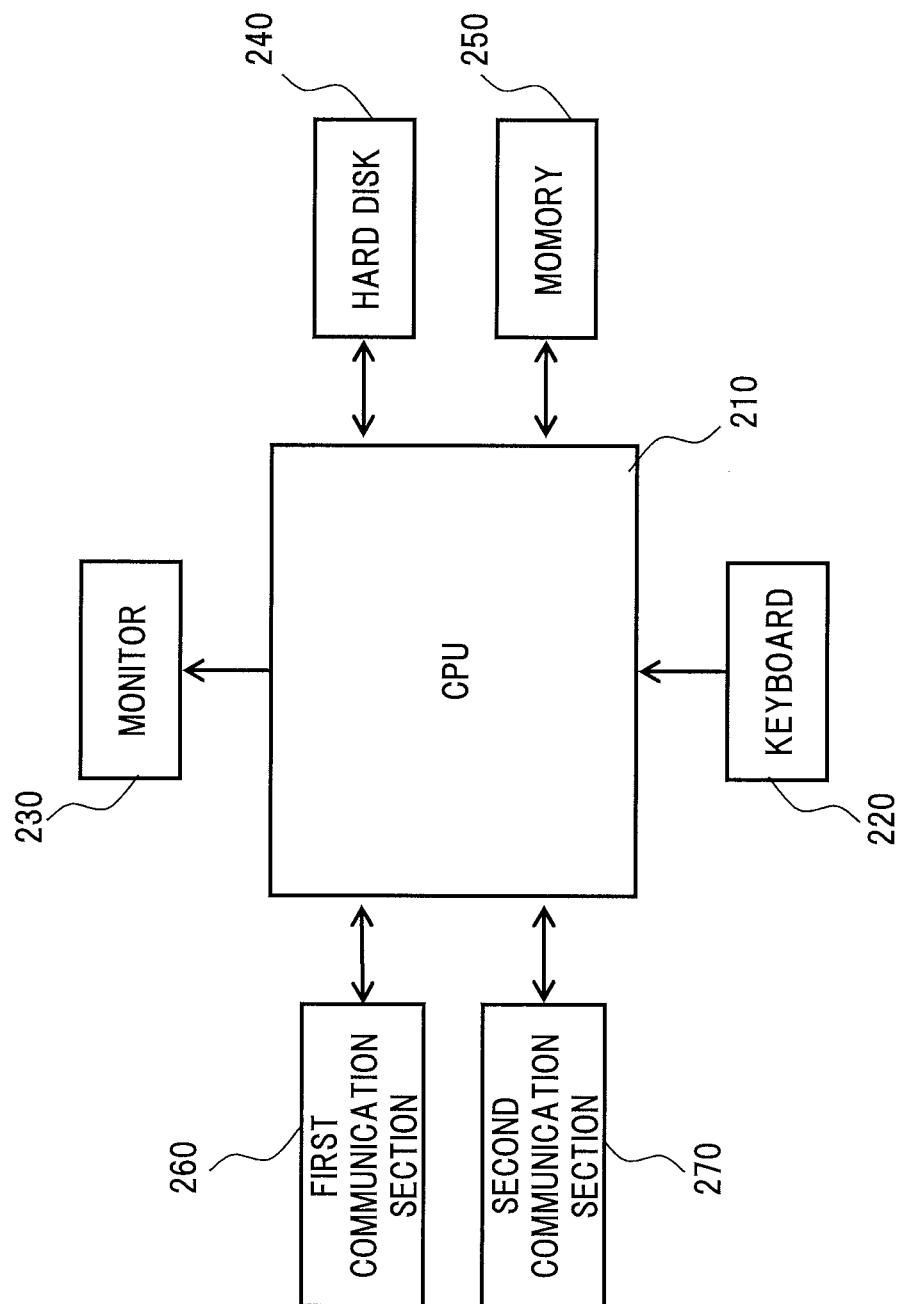
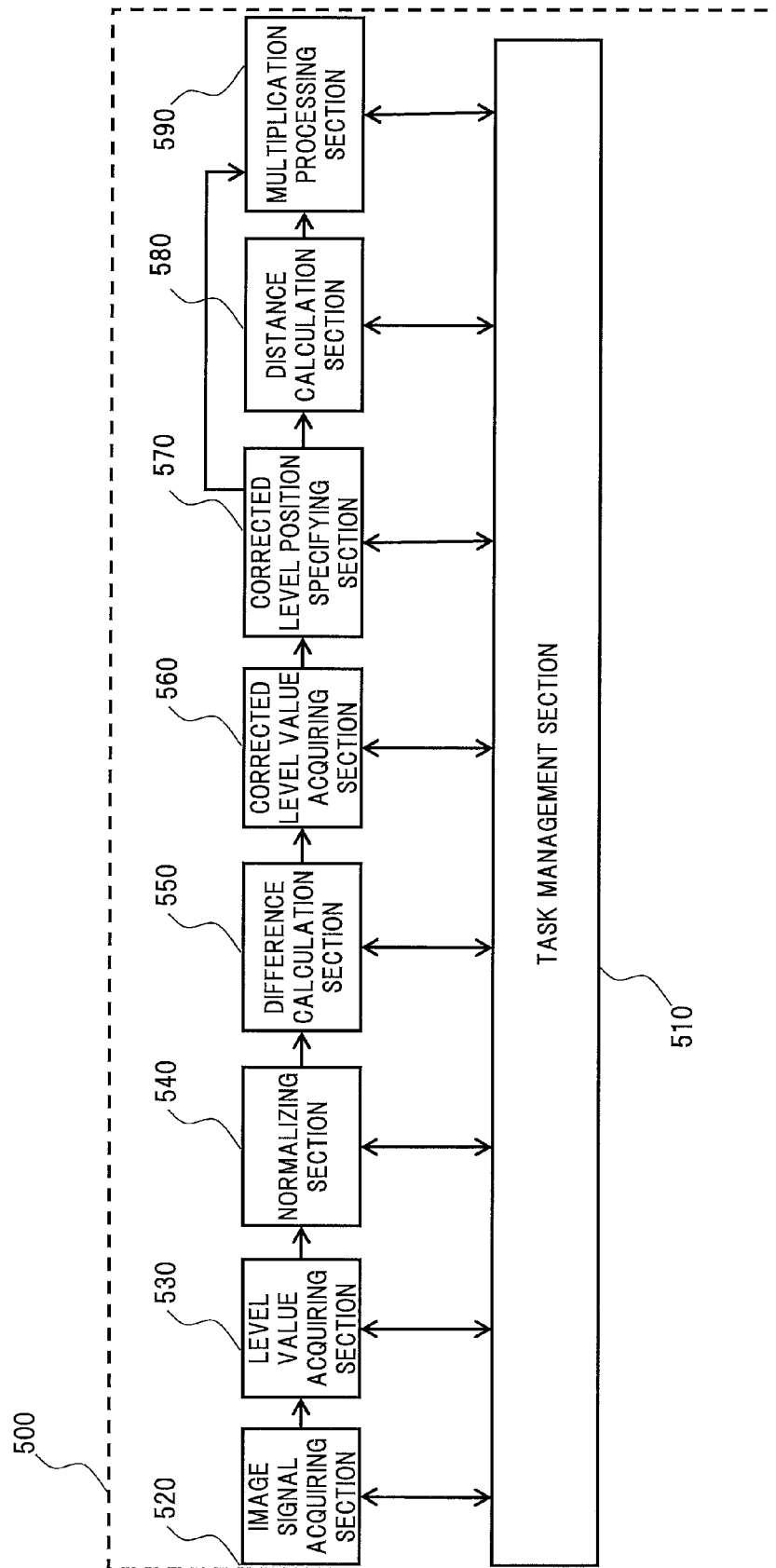


FIG. 11

FIG. 12



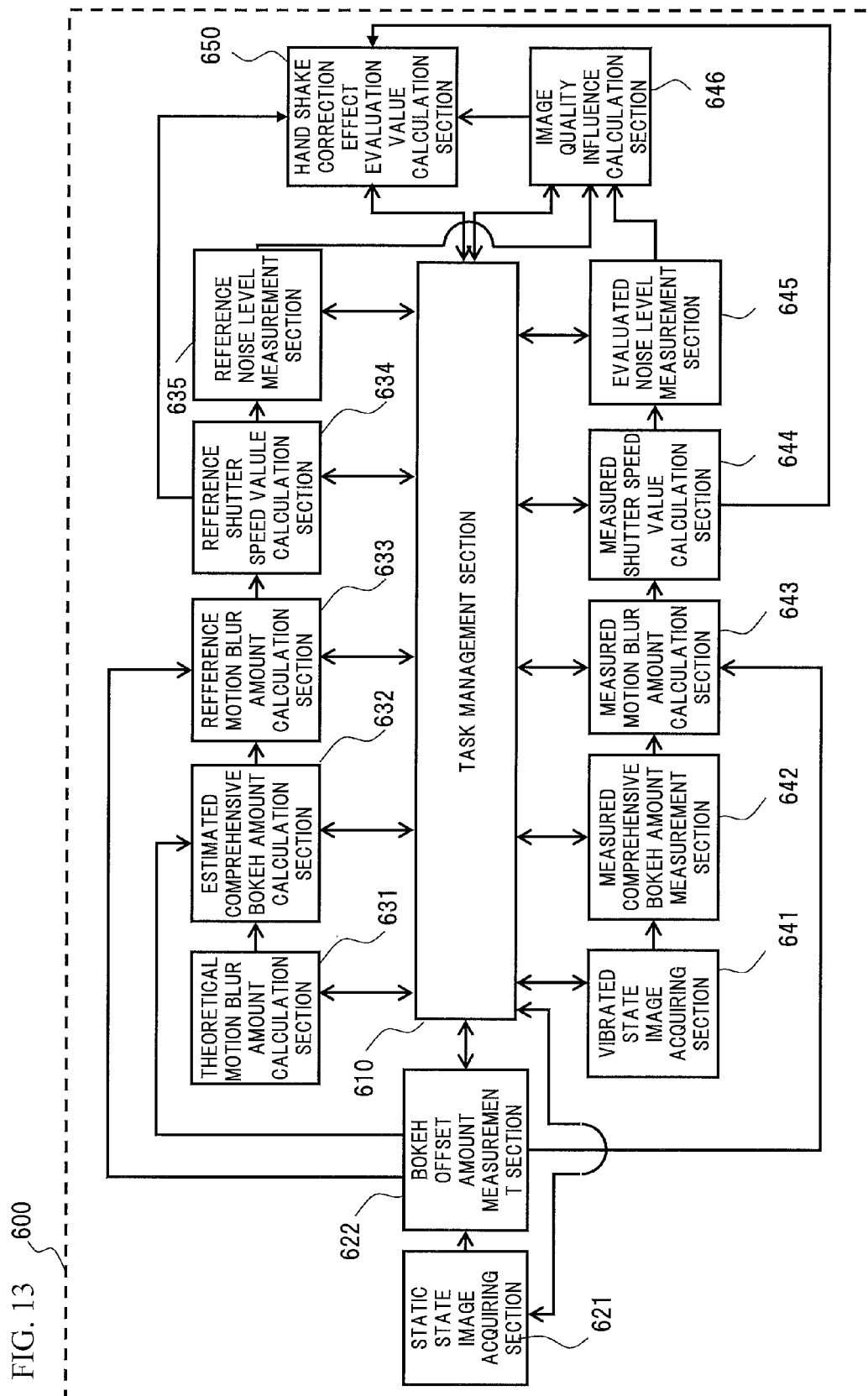


FIG. 14

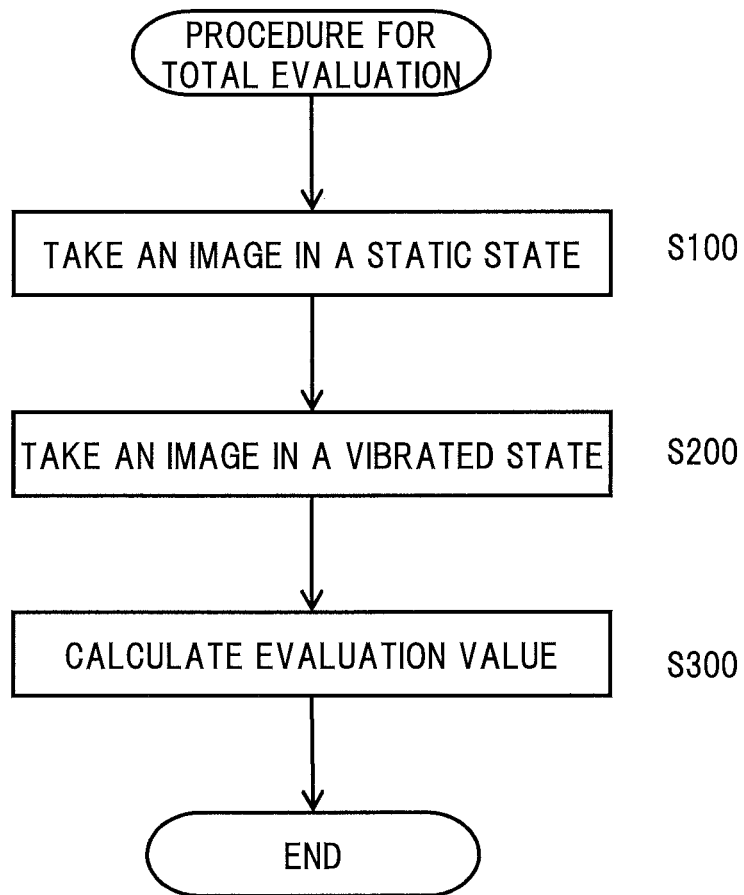


FIG. 15

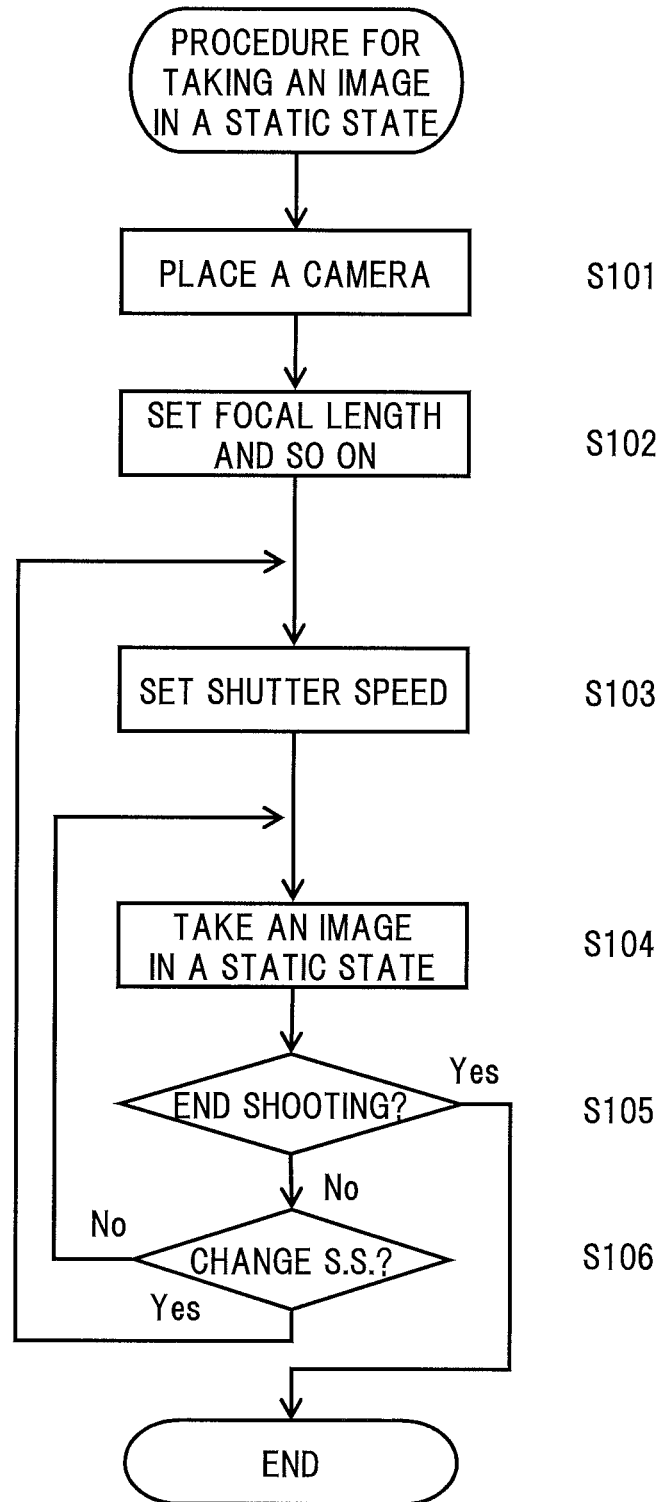


FIG. 16

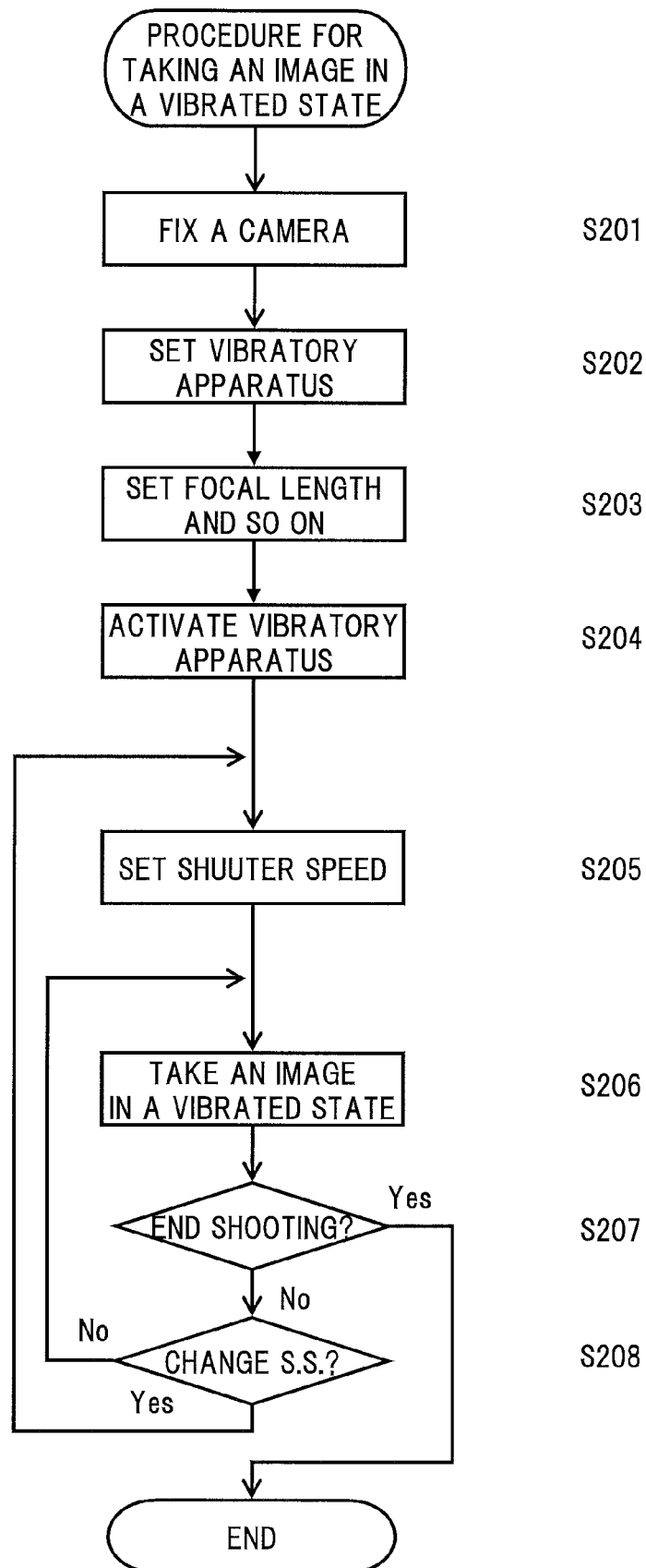


FIG. 17

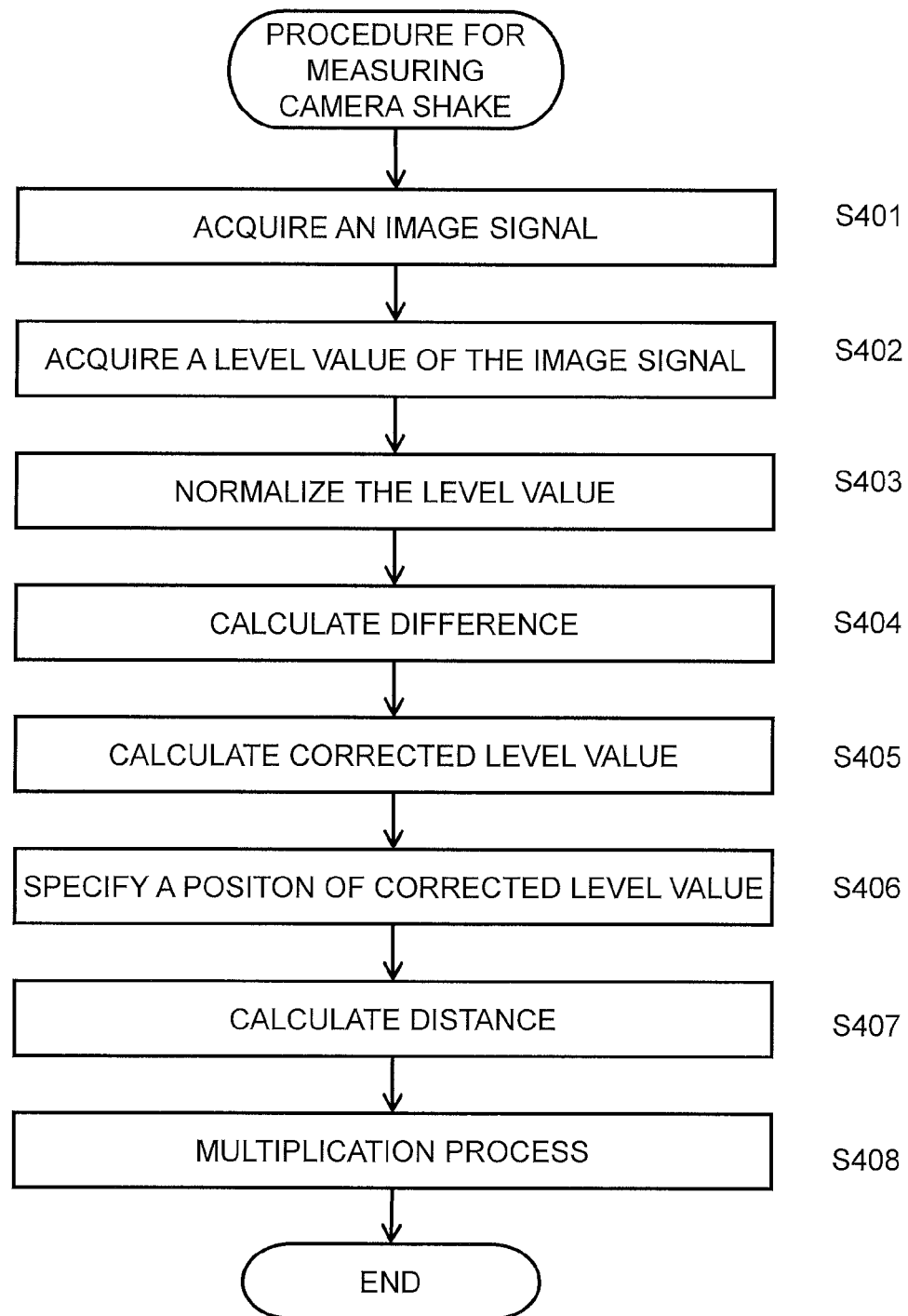


FIG. 18

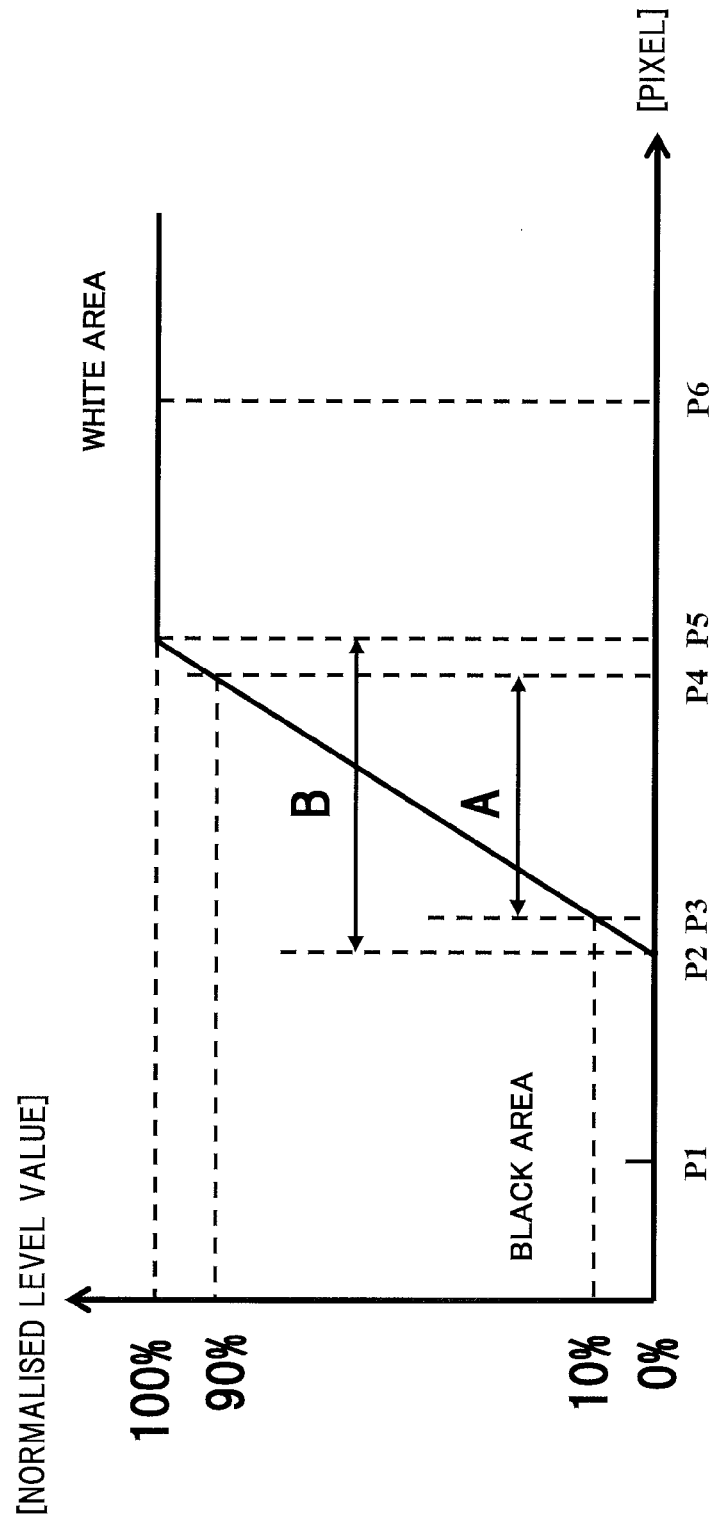


FIG. 19

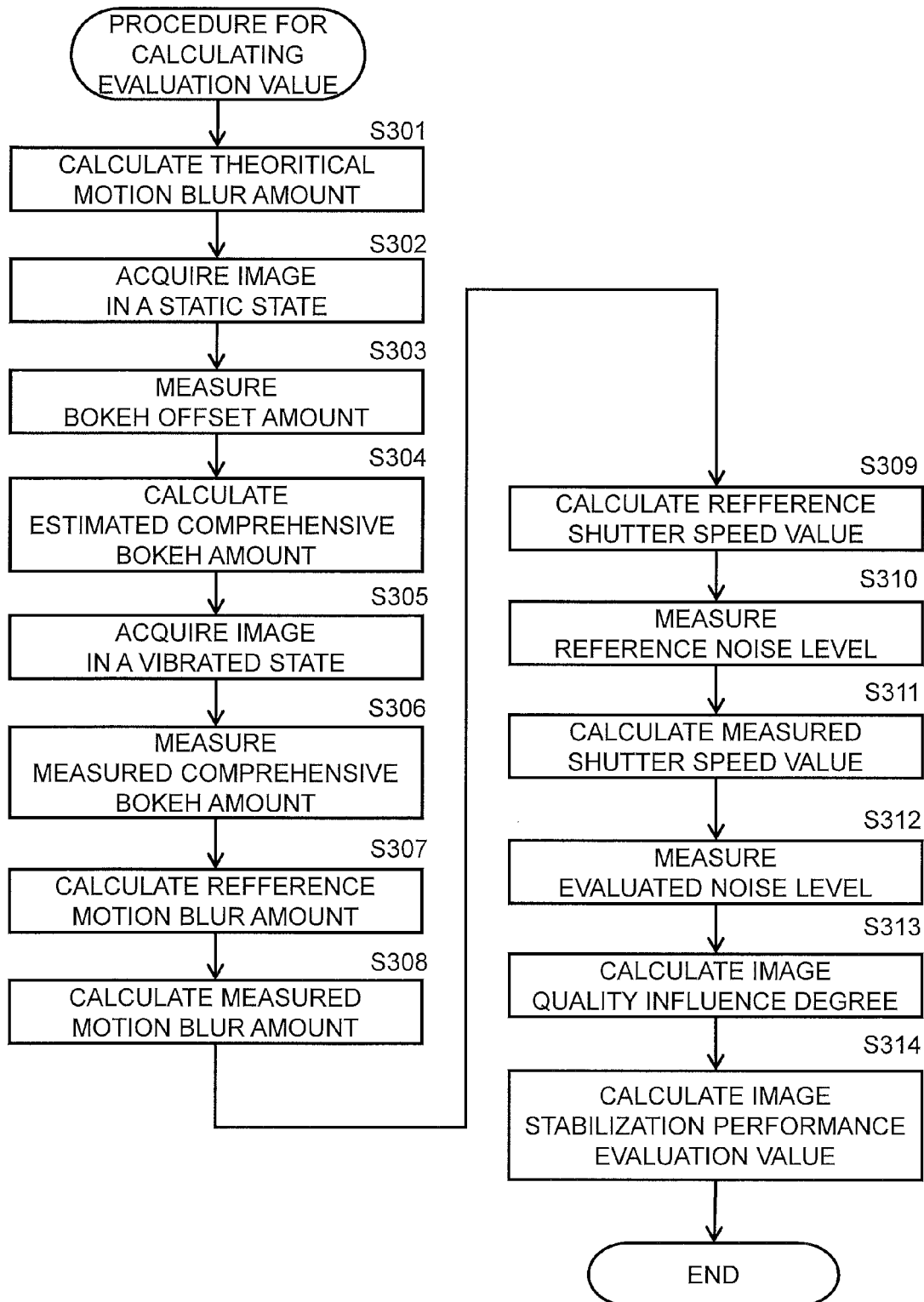


FIG. 20

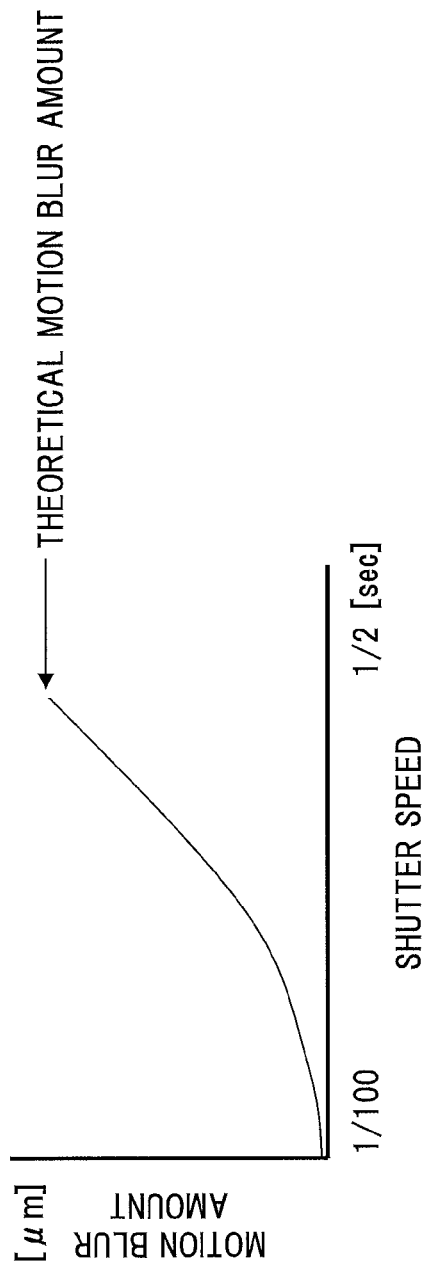


FIG. 21

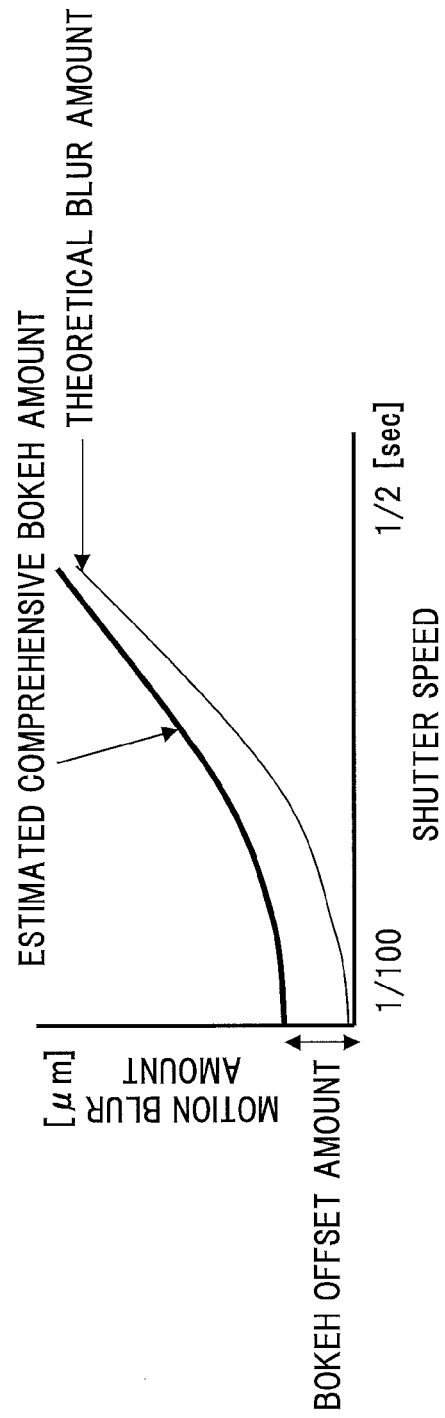


FIG. 22

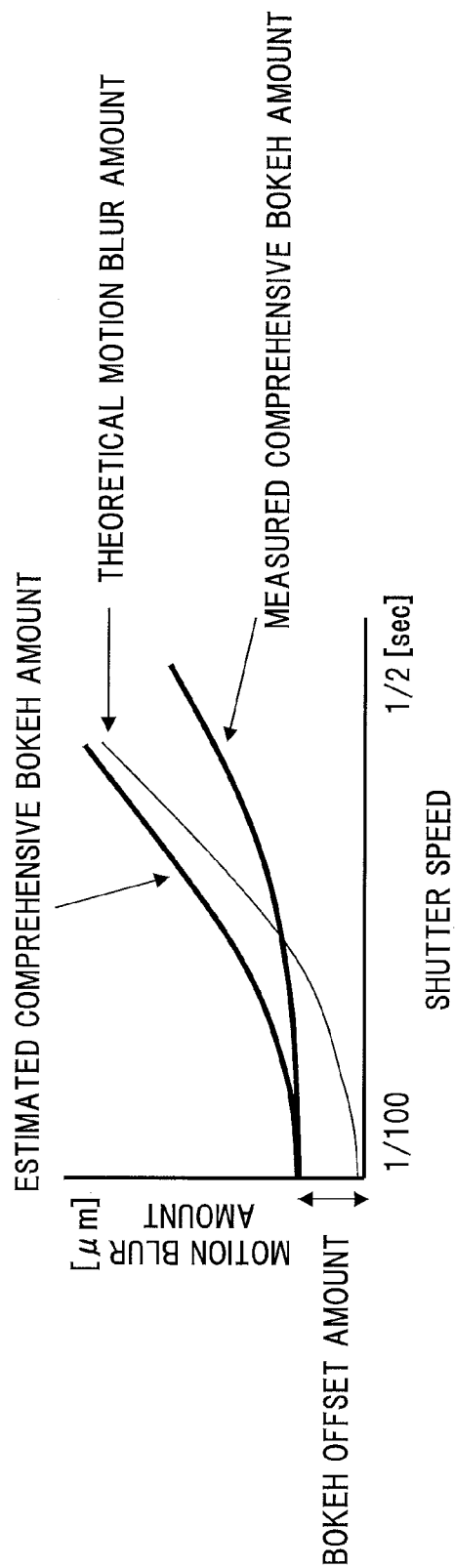


FIG. 23

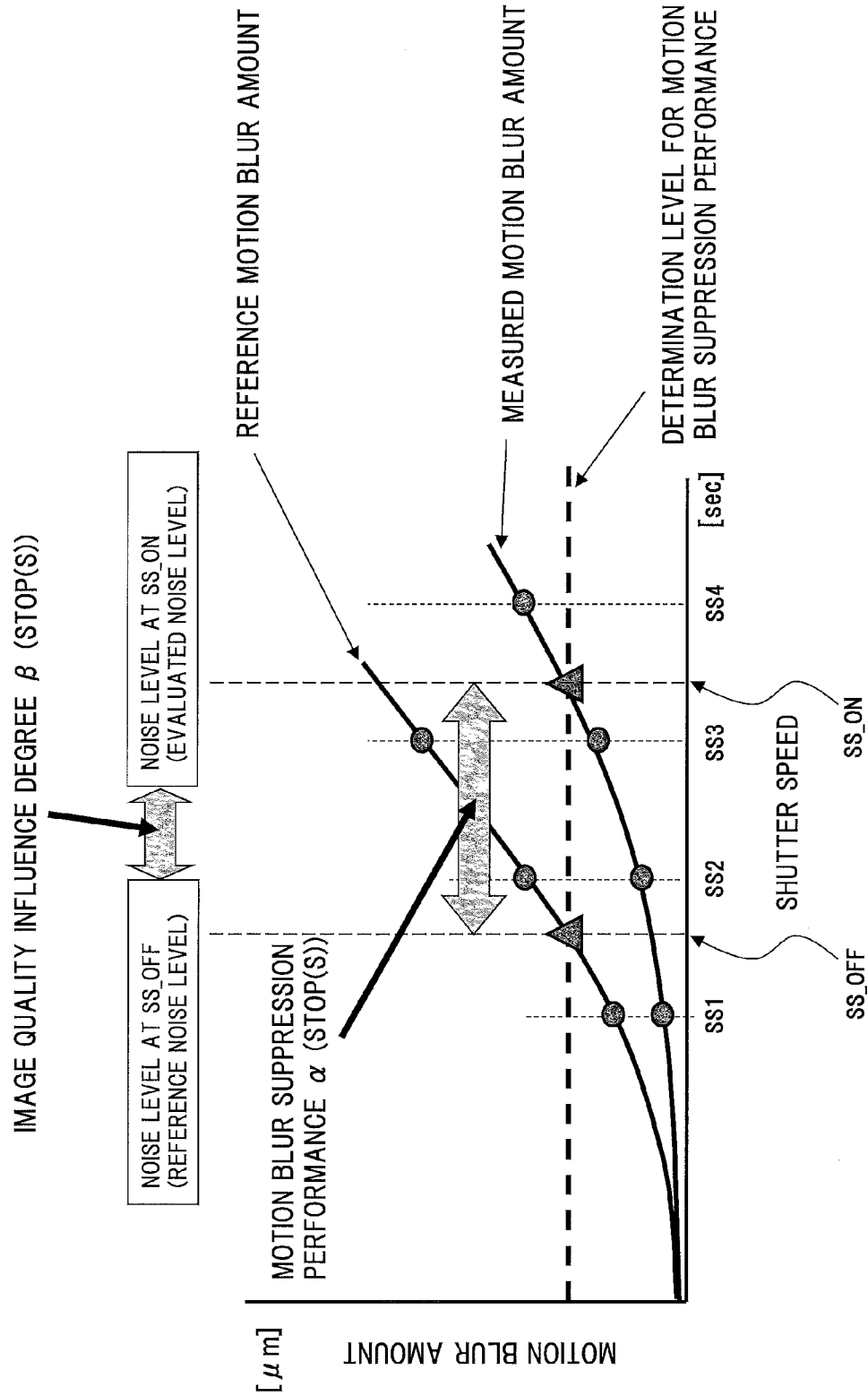


FIG. 24

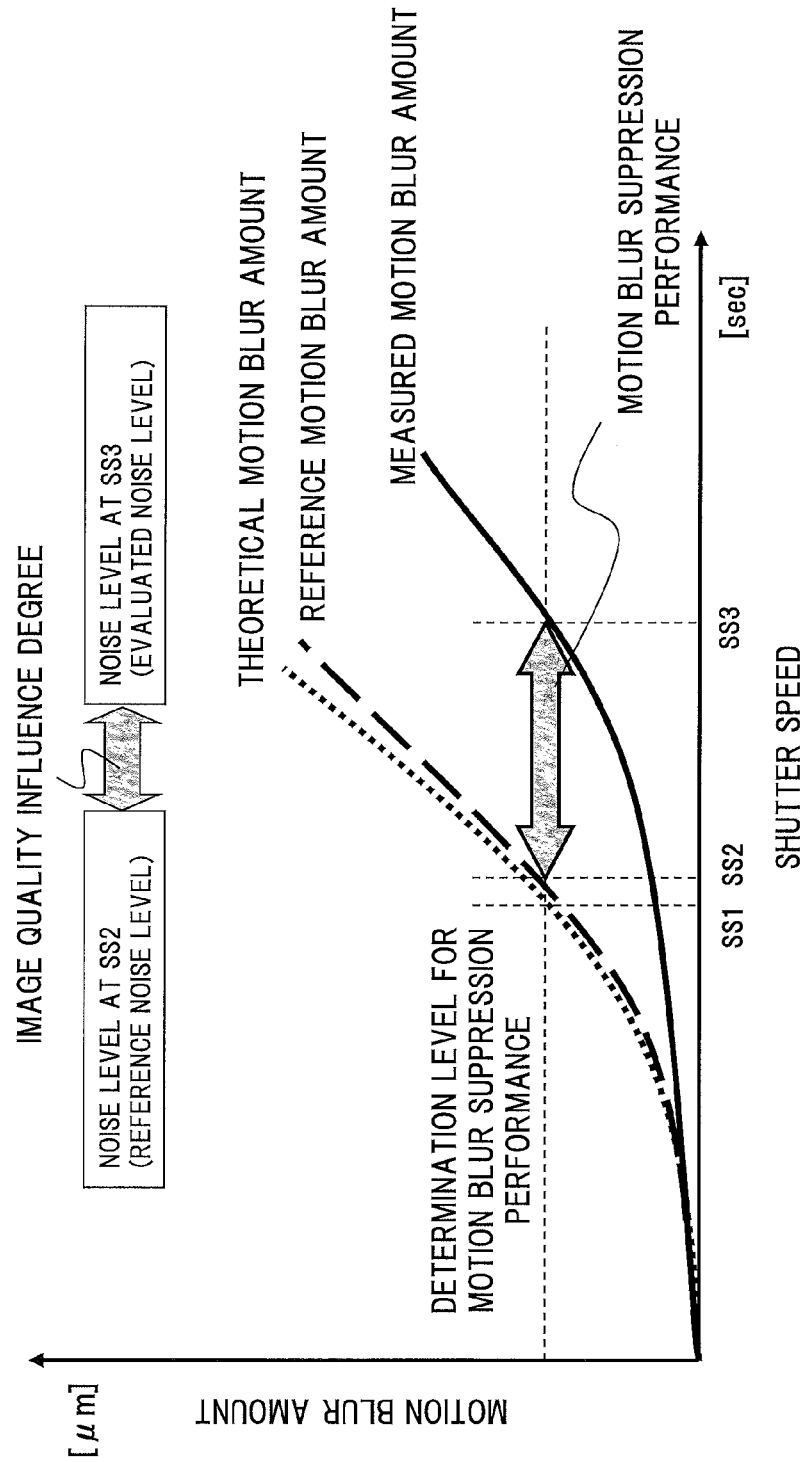


FIG. 25

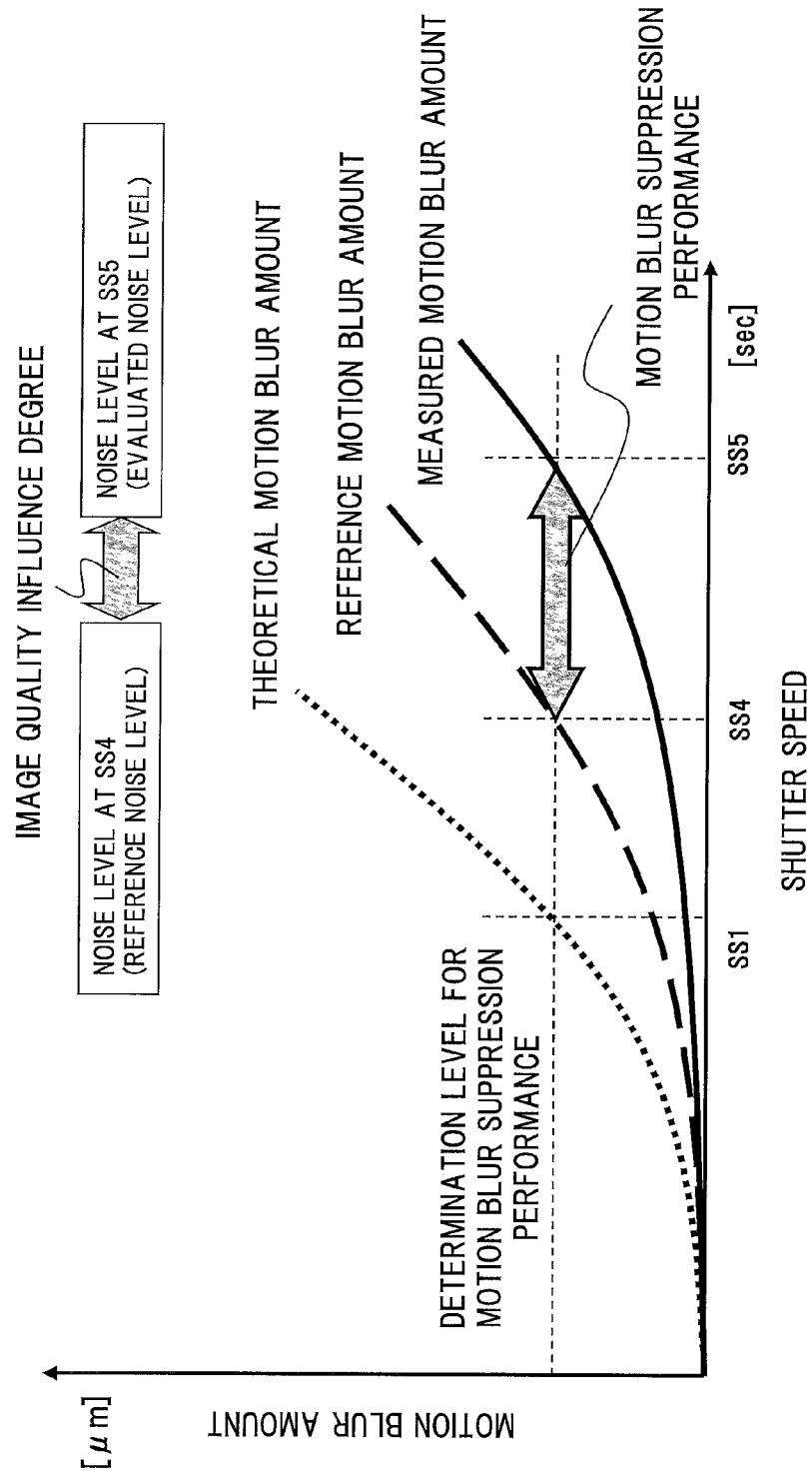


FIG. 26

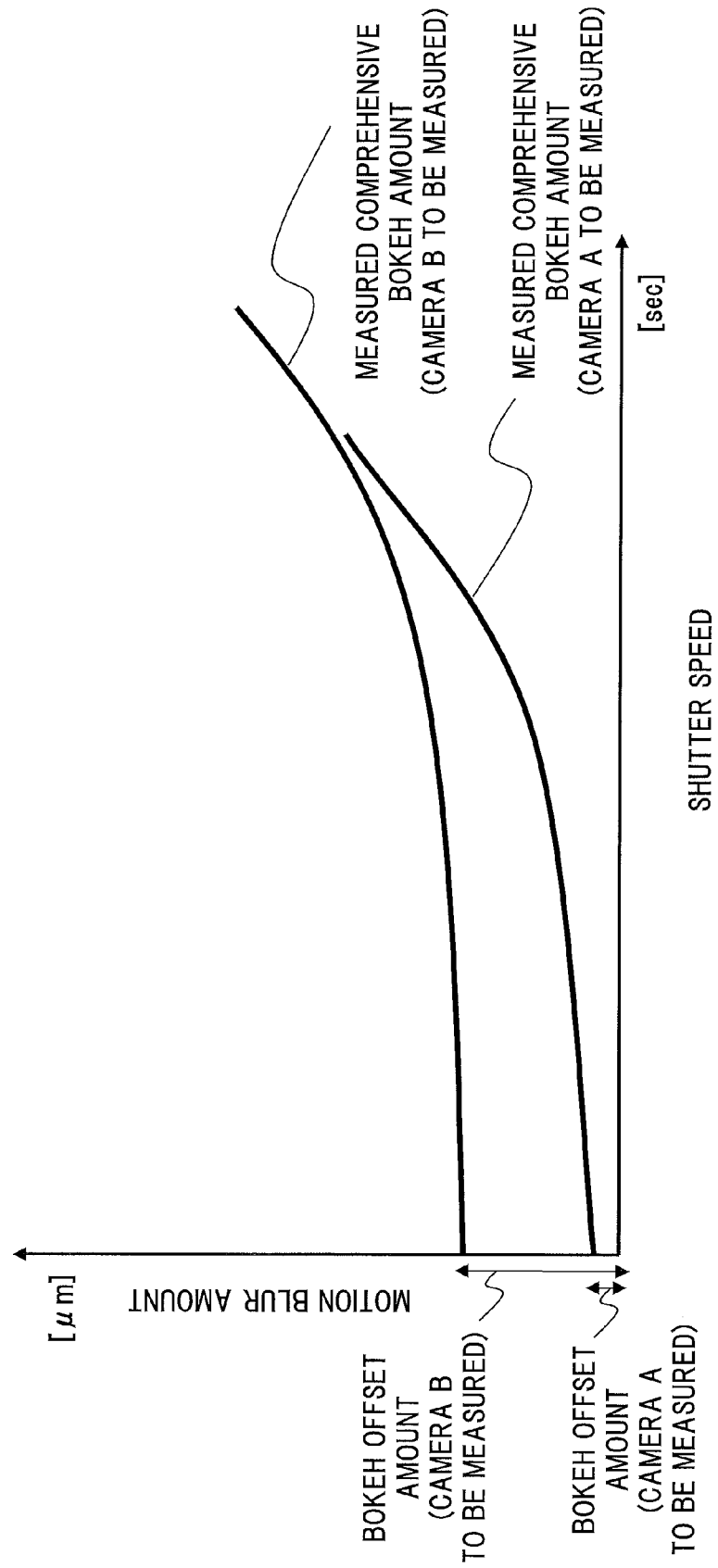
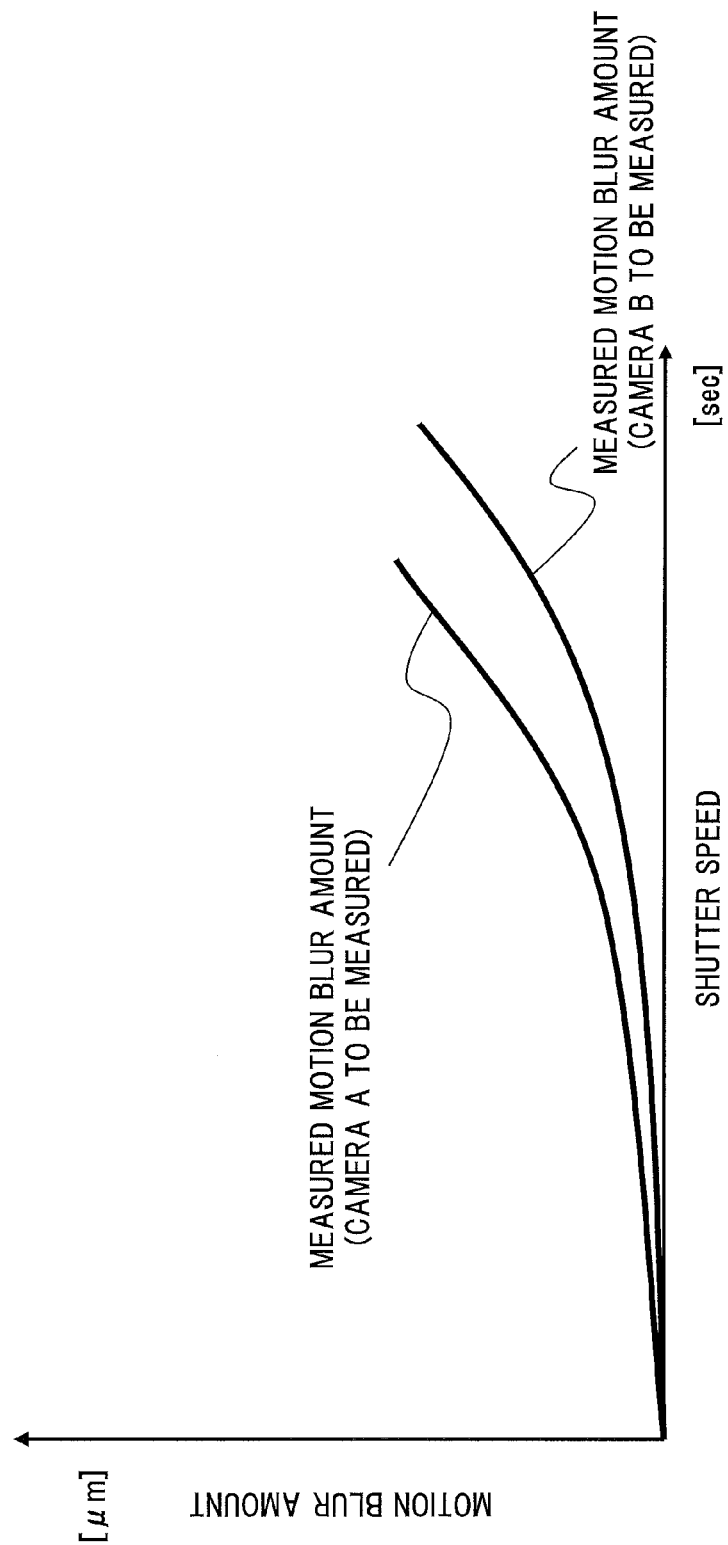


FIG. 27



**EVALUATION METHOD, EVALUATION  
APPARATUS, COMPUTER READABLE  
RECORDING MEDIUM HAVING STORED  
THEREIN EVALUATION PROGRAM**

**CROSS REFERENCE TO RELATED  
APPLICATION**

The disclosure of International Patent Application No. PCT/JP2013/000579 filed on Feb. 1, 2013, which claims priority based on Japanese Patent Application No. 2012-021980 filed on Feb. 3, 2012 is incorporated herein by reference.

**BACKGROUND OF THE INVENTION**

**1. Field of the Invention**

The present disclosure relates to an evaluation method, an evaluation apparatus, a computer program for evaluation, and a computer readable recording medium having stored therein the computer program, which are used for evaluating the performance of an image stabilization function of a camera.

**2. Description of the Background Art**

Japanese Laid-Open Patent Publication No. 2008-289122 discloses an evaluation method for an image in which a shaking table holding an imaging apparatus is shaken based on a model waveform, a predetermined object is imaged by the imaging apparatus with the shaking table being shaken, and the image taken by the imaging apparatus is evaluated. Here, the model waveform is generated by acquiring a plurality of pieces of vibration information about a shake given to the imaging apparatus when a photographer takes an image of an object, and then performing statistic processing for frequency information of all or some of the acquired pieces of vibration information.

Japanese Laid-Open Patent Publication No. 2009-211023 discloses an evaluation method of calculating an evaluation value of the performance of an image stabilization function of a camera by using an image taken by a camera being shaken, with its image stabilization function being ON.

**SUMMARY OF THE INVENTION**

The present disclosure has an object to provide an evaluation method and the like which can evaluate the performance of an image stabilization function of a camera.

In order to achieve the above object, an evaluation method of the present disclosure is an evaluation method for evaluating the performance of an image stabilization function of an imaging apparatus, the evaluation method including: a first imaging step of imaging an object, with the image stabilization function being ON and the imaging apparatus being vibrated; a second imaging step of imaging the object, with the imaging apparatus being static; a first calculation step of detecting a motion blur amount based on an image taken in the first imaging step, calculating a first shutter speed that causes the detected motion blur amount to be a predetermined amount, and calculating, based on the first shutter speed and a reference shutter speed obtained from information relating to the vibration given to the imaging apparatus, a first evaluation value indicating a difference between the first shutter speed and the reference shutter speed; a second calculation step of calculating a second evaluation value indicating a difference in image quality between the image taken in the first imaging step and the image taken in the second imaging step; and an evaluation step of calculating an evaluation value of the performance of the image stabilization function of the

imaging apparatus, based on a result of subtraction of the second evaluation value from the first evaluation value.

It is noted that the evaluation method of the present disclosure can be realized as an evaluation apparatus or a computer program. In addition, the computer program realizing the evaluation method of the present disclosure can be stored in a storage medium such as an optical disc, a memory card, a magnetic disk, a hard disk, or a magnetic tape.

Further, means to realize the evaluation method of the present disclosure may be included in a camera. The means to realize the evaluation method of the present disclosure may be configured as a computer program or a wired logic.

According to the present disclosure, an evaluation method and the like which can evaluate the performance of an image stabilization function of a camera is provided.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic diagram showing the configuration of an evaluation system;

FIG. 2 is a plane view of a motion blur measurement chart;

FIG. 3 is a block diagram showing the configuration of a camera to be measured;

FIG. 4 is a diagram for explaining definition of a total exposure time;

FIG. 5 is a block diagram showing the configuration of a vibratory apparatus;

FIG. 6 is a graph showing an example of vibration data for a camera having a small mass;

FIG. 7 is a graph showing an example of vibration data for a camera having a large mass;

FIG. 8 is a flowchart showing a procedure for generating vibration data;

FIG. 9 is a schematic diagram for explaining a procedure for generating vibration data;

FIG. 10 is a schematic diagram for explaining a generation procedure for vibration data;

FIG. 11 is a block diagram showing the configuration of a computer;

FIG. 12 is a block diagram showing the configuration of motion blur measurement software;

FIG. 13 is a block diagram showing the configuration of evaluation value calculation software;

FIG. 14 is a flowchart showing the whole evaluation procedure;

FIG. 15 is a flowchart showing an imaging procedure in a static state;

FIG. 16 is a flowchart showing an imaging procedure in a vibrated state;

FIG. 17 is a flowchart showing a camera shake measurement procedure;

FIG. 18 is a schematic diagram for explaining a method of measuring camera shake;

FIG. 19 is a flowchart showing an evaluation value calculation procedure;

FIG. 20 is a graph showing the trajectory of a theoretical motion blur amount;

FIG. 21 is a graph showing the relationship among a theoretical motion blur amount, a bokeh offset amount, and an estimated comprehensive bokeh amount;

FIG. 22 is a graph showing the trajectories of an estimated comprehensive bokeh amount and a measured comprehensive bokeh amount;

FIG. 23 is a graph showing a calculation method for an evaluation value of an image stabilization performance;

FIG. 24 is a characteristic diagram for a camera A to be measured;

FIG. 25 is a characteristic diagram for a camera B to be measured;

FIG. 26 is a graph showing the trajectory of a measured comprehensive bokeh amount;

FIG. 27 is a graph showing a result of subtraction of a bokeh offset amount from a measured comprehensive bokeh amount.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments will be described in detail by referring the drawings as necessary. However, there will be instances in which detailed description beyond what is necessary is omitted. For example, detailed description of subject matter that is previously well-known, as well as redundant description of components that are substantially the same will in some cases be omitted. This is to prevent the following description from being unnecessarily lengthy, in order to facilitate understanding by a person of ordinary skill in the art.

The inventors provide the following description and the accompanying drawings in order to allow a person of ordinary skill in the art to sufficiently understand the present disclosure, and the description and the drawings are not intended to restrict the subject matter of the scope of the patent claims.

#### Embodiment 1

##### 1. Configuration of Measurement System

FIG. 1 is a block diagram showing the configuration of a measurement system according to embodiment 1.

The measurement system according to embodiment 1 is a system for measuring the performance of an image stabilization function of a camera 400 to be measured, by imaging a motion blur measurement chart 300 with the camera 400 to be measured in the state in which the camera 400 to be measured is fixed on a vibratory table 120 of a vibratory apparatus 100, and by analyzing the obtained image by a computer 200 camera 400 to be measured.

Here, a camera shake means that a camera moves because a hand holding the camera is unstable, resulting in subject shake in a shot image. In addition, the image stabilization function refers to a function of correcting a bokeh in an output image caused by the motion of a camera due to camera shake, by using the output of camera shake detection means. A motion blur amount is an amount corresponding to the movement of an object on a shot image caused by camera shake.

The vibratory apparatus 100 vibrates the vibratory table 120 by a pitch direction vibrating mechanism 140 and a yaw direction vibrating mechanism 130. The yaw direction vibrating mechanism 130 is a mechanism for giving a vibration around the X axis in FIG. 1. That is, the yaw direction vibrating mechanism 130 gives the vibratory table 120 a vibration simulating a camera shake in the horizontal direction around the vertical axis caused upon imaging by the camera 400 to be measured in a right posture. The vibration around the X axis is referred to as a yaw direction vibration. In addition, the pitch direction vibrating mechanism 140 is a mechanism for giving a vibration around the Y axis in FIG. 1. That is, the pitch direction vibrating mechanism 140 gives the vibratory table 120 a vibration simulating a camera shake in the vertical direction around the horizontal axis perpendicular to an opti-

cal axis upon imaging by the camera 400 to be measured in a right posture. The vibration around the Y axis is referred to as a pitch direction vibration.

The vibratory table 120 can fix the camera 400 to be measured by some means. For example, the camera 400 to be measured may be fixed by screw fastening, or may be fixed by an adhesive tape. Any fixing means may be used but it is necessary that the fixing is not easily released when a vibration is given to the camera 400 to be measured. The vibratory table 120 transmits the vibration given by the yaw direction vibrating mechanism 130 and the pitch direction vibrating mechanism 140, to the camera 400 to be measured.

A release button pressing mechanism 150 is for pressing a release button 471 of the camera 400 to be measured. The release button pressing mechanism 150 may be composed of a solenoid mechanism, for example. It is noted that in embodiment 1, the release button 471 is mechanically pressed by the release button pressing mechanism 150, to perform shutter release of the camera 400 to be measured. However, the shutter release may be performed by another method. For example, the camera 400 to be measured itself may perform release by an electric signal being transmitted to the camera 400 to be measured via wire or wirelessly. Alternatively, an evaluator may manually press the release button 471. Still alternatively, in the case of mechanically pressing the release button 471 by the release button pressing mechanism 150, a vibration due to the pressing may be applied to the camera 400 to be measured.

A vibratory controller 110 controls the entire vibratory apparatus 100 including the yaw direction vibrating mechanism 130, the pitch direction vibrating mechanism 140, the release button pressing mechanism 150, and the like.

The computer 200 is, for example, a personal computer, and performs transmission and reception of a signal with the vibratory apparatus 100 and the camera 400 to be measured. The computer 200 gives information about shutter release or vibration data to the vibratory controller 110, and acquires a shot image from the camera 400 to be measured. Transmission and reception of a signal between the computer 200 and the vibratory apparatus 100 or the camera 400 to be measured may be performed via wire or wirelessly. In addition, acquisition of a shot image from the camera 400 to be measured may be performed by wired or wireless communication or via a memory card.

##### [1-1. Motion Blur Measurement Chart]

FIG. 2 shows an example of a motion blur measurement chart 300. The motion blur measurement chart 300 is a chart used as an object to be imaged upon measurement of the image stabilization performance. A black area 301 is an area colored in black. A white area 302 is an area colored in white. An imaging area marker 303 is a marker used as a reference for setting an imaging area. A gray area 304 is an area colored in gray and having a reflectance of 18%, for example. The gray area 304 is, as described later, an area used for measurement and calculation of a noise level of a shot image. In addition, the gray area 304 may be disposed at a position or a plurality of positions on the blur measurement chart 300. There may be a case where the gray area 304 and the black area 301 overlap each other in an image taken during vibration and thereby a noise level cannot be correctly measured. Therefore, in the blur measurement chart 300, the gray area 304 and the black area 301 are preferably disposed at a distance from each other. More preferably, the gray area 304 is disposed at a plurality of positions because, in this case, an area where the gray area 304 and the black area 301 do not overlap each other is more likely to remain in the image taken during vibration. If the size of the gray area 304 is too small,

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there may be a case where a noise level cannot be correctly measured because of overlapping of the gray area **304** and white area **302** in the image taken during vibration. Therefore, the size of the gray area **304** is preferably as large as possible.

The motion blur measurement chart **300** is not limited to that shown in FIG. 2, and various types may be applied thereto. For example, instead of a combination of black, white, and gray, the motion blur measurement chart **300** may be a pattern composed of several kinds of color areas having chroma. Alternatively, instead of such a geometric pattern, the motion blur measurement chart **300** may partially include a real picture. Further, although the gray area **304** colored in gray and having a reflectance of 18% is disposed, an area having any chroma and any reflectance may be disposed. Further, although the gray area **304** is used for measurement and calculation of a noise level of a shot image, a noise level may be measured by using the black area **301** or the white area **302** without providing the gray area **304**.

In essence, the motion blur measurement chart **300** may be a chart including a plurality of color areas. In embodiment 1, a bokeh amount of an image is evaluated by measuring a bokeh of the image at the boundary between different color areas of the motion blur measurement chart. Here, color of the color area is a concept including black, gray, and white which have no chroma and also including colors having chroma. In addition, a bokeh refers to a phenomenon in which the sharpness of a shot image reduces due to displacement between the focus plane of a lens and an imaging plane of an imaging device, camera shake, or the like. The bokeh can occur due to image processing for image data. A bokeh amount refers to a value obtained by quantifying the magnitude of a bokeh.

[1-2. Example of Camera to be Measured]

FIG. 3 is a block diagram showing an exemplary configuration of the camera to be measured. The camera **400** to be measured generates image data by a CCD image sensor **420** taking an object image formed in an optical system **410**.

The optical system **410** includes a zoom lens **411**, a mechanical shutter **413**, a camera shake correcting lens **414**, a focus lens **416**, and the like. The zoom lens **411** is movable along the optical axis of the optical system **410**, and can change the focal length by the movement. A zoom motor **412** drives the zoom lens **411** along the optical axis. The mechanical shutter **413** transmits or shuts off light entering the CCD image sensor **420** upon imaging, in accordance with control from the controller **440**. The length of time during which the light is transmitted upon imaging is referred to as a shutter speed or an exposure time. The camera shake correcting lens **414** moves on a plane perpendicular to the optical axis, whereby a subject shake on an image formed on the CCD image sensor **420** plane can be reduced. Therefore, owing to the camera shake correcting lens **414**, the camera **400** to be measured has an optical image stabilization function. Here, since the optical image stabilization function of the camera **400** to be measured is realized by the camera shake correcting lens **414**, in other words, it can be said that the camera **400** to be measured is a camera having an optical image stabilization function of an inner lens shift type. An actuator **415** drives the camera shake correcting lens **414** on a plane perpendicular to the optical axis. The focus lens **416** is movable along the optical axis, and can change the focus state of an object image along the optical axis.

The CCD image sensor **420** generates image data by taking an object image formed by the optical system **410**. A timing generator **421** transmits a synchronization signal to the CCD image sensor **420** in accordance with an instruction from the controller **440**. By variously changing the synchronization

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signal, the operation of the CCD image sensor **420** is controlled. An AD converter **430** converts image data generated by the CCD image sensor **420** from an analog signal to a digital signal.

The controller **440** controls the whole camera **400** to be measured. The controller **440** can be realized by a microcomputer, for example. In addition, the controller **440** may be composed of one semiconductor chip or may be composed of a semiconductor chip for realizing an image processing section and a semiconductor chip for realizing an operation control section. Further, the controller **440** can subject a shot image to electronic image stabilization by image processing. In other words, the camera **400** to be measured is a camera having an electronic image stabilization function.

A card slot **450** allows a memory card **451** to be attached thereto, and performs transmission and reception of data with the memory card **451**. A communication section **460** performs transmission and reception of data with the computer **200**. An operation section **470** is composed of a cross key, a press button, a touch panel, or the like, and is a member for making various settings of the camera **400** to be measured. The release button **471** is an operation member for giving an instruction for shutter release to the controller **440** by a pressing operation from a user.

A gyro sensor **480** is a sensor for measuring an angular velocity. By fixing the gyro sensor **480** on the camera **400** to be measured, the amount of a vibration given to the camera **400** to be measured can be measured. Based on information from the gyro sensor **480**, the controller **440** controls the actuator **415** so as to drive the camera shake correcting lens **414** in a direction that cancels the camera shake. Thus, an optical image stabilization function of the camera **400** to be measured is realized.

It is noted that the camera **400** to be measured described above is merely an example of a camera to be measured. Besides the camera **400** to be measured, the measurement method according to embodiment 1 can apply to measurement of the performance of an image stabilization function of various cameras as long as the camera has an image stabilization function. For example, although the camera **400** to be measured is a camera provided with a zoom lens, a single-focus camera may be used. In addition, although the camera **400** to be measured is a camera having an optical image stabilization function of an inner lens shift type, the measurement method according to embodiment 1 is also applicable to a camera having an optical image stabilization function of another type such as an imaging device shift type. In addition, although the camera **400** to be measured is a camera having a built-in lens unit, a camera with interchangeable lenses such as a single-lens reflex camera can also be measured. In this case, instead of evaluation of only a camera itself, a camera system including the interchangeable lenses is evaluated. In addition, although the camera **400** to be measured is a camera that performs exposure by a mechanical shutter, a camera that performs exposure by an electronic shutter may be used. In addition, although in the above description, a simple configuration has been shown as the optical system **410** for facilitating the description, the optical system may include more lenses.

Subsequently, the electronic image stabilization function will be briefly described.

First, as camera shake measurement means, for example, means for measuring a camera shake by a sensor, such as a gyro sensor, attached on a camera in order to detect a camera shake, and means for measuring a camera shake by analyzing an image shot with a camera are conceivable.

Next, as electronic image stabilization methods, a method of reducing blurring of a shot image by image processing such as image recovery or image restoration, and a method of taking a plurality of images with a short exposure time and then combining the shot images are conceivable. The camera 400 to be measured according to embodiment 1 adopts a method of taking a plurality of images with a short exposure time, and combining the images while changing an area to be cut from the shot images such that the positions of the corresponding objects in the plurality of images coincide with each other. It is noted that, when this method is adopted, it is not generally determined whether the "exposure time" is an exposure time for one of the plurality of shot images or the total of exposure times for the plurality of shot images.

In embodiment 1, the exposure time when the electronic image stabilization is adopted is referred to as "total exposure time". In order to evaluate the image stabilization performance according to embodiment 1, the "total exposure time" is defined as shown in FIG. 4. FIG. 4 is a diagram for explaining the definition of the total exposure time.

FIGS. 4(1) to 4(3) each show an exposure time when no electronic image stabilization is used, and an exposure time per shot image when electronic image stabilization is used. Specifically, in FIGS. 4(1) to 4(3), the exposure time when no electronic image stabilization is used is  $\frac{1}{2}$  sec. The exposure time per shot image when electronic image stabilization is used, and the number of shot images used for evaluation of image stabilization performance vary among FIGS. 4(1) to 4(3).

FIG. 4(1) shows a case where four images (Ai, Bi, Ci, and Di) are taken with an exposure time of  $\frac{1}{8}$  sec when electronic image stabilization is used. It is assumed that the four images (Ai, Bi, Ci, and Di) taken when electronic image stabilization is used have been used for an image combination process in the electronic image stabilization. At this time, the total exposure time is the total of the exposure times for the four images. That is, the total exposure time is expressed by  $Ai (\frac{1}{8} \text{ sec}) + Bi (\frac{1}{8} \text{ sec}) + Ci (\frac{1}{8} \text{ sec}) + Di (\frac{1}{8} \text{ sec}) = \frac{4}{8} \text{ sec} (\frac{1}{2} \text{ sec})$ .

FIG. 4(2) shows a case where three images (Aii, Bii, and Cii) are taken when electronic image stabilization is used. The first image Aii is taken with an exposure time of  $\frac{1}{4}$  sec, and the second and third images Bii and Cii are each taken with an exposure time of  $\frac{1}{8}$  sec. It is assumed that all the three images (Aii, Bii, and Cii) taken when electronic image stabilization is used have been used for the image combination process in the electronic image stabilization. At this time, the total exposure time is the total of the exposure times of the three images. That is, the total exposure time is expressed by  $Aii (\frac{1}{4} \text{ sec}) + Bii (\frac{1}{8} \text{ sec}) + Cii (\frac{1}{8} \text{ sec}) = \frac{3}{8} \text{ sec} (\frac{1}{2} \text{ sec})$ .

FIG. 4(3) shows a case where four images (Aiii, Biii, Ciii, and Diii) are each taken with an exposure time of  $\frac{1}{8}$  sec when electronic image stabilization is used. It is assumed that, among the four images (Aiii, Biii, Ciii, and Diii) taken when electronic image stabilization is used, the images Aiii, Biii, and Diii have been used for the image combination process in the electronic image stabilization, whereas the image Ciii has not been used for the image combination process in the electronic image stabilization. At this time, the total exposure time is the total of the exposure times of the three images used for the image combination process in the electronic image stabilization. That is, the total exposure time is expressed by  $Aiii (\frac{1}{8} \text{ sec}) + Biii (\frac{1}{8} \text{ sec}) + Diii (\frac{1}{8} \text{ sec}) = \frac{3}{8} \text{ sec}$ .

As described above, in the evaluation of the image stabilization performance according to embodiment 1, the total of the exposure times of the shot images used for the image combining process in the electronic image stabilization is defined as the total exposure time. Then, the total exposure

time is defined as a shutter speed of an image obtained by the electronic image stabilization.

Although there are a variety of electronic image stabilization methods, the measurement method according to embodiment 1 is applicable to any of the above-mentioned electronic image stabilization methods. Specifically, procedures such as an evaluation value calculation procedure taking a bokeh offset amount into consideration, a motion blur amount measurement procedure of actually measuring a distance in a specific level range and estimating a bokeh amount at the boundary between different color areas based on the measurement, and a calculation procedure for an evaluation value indicating the performance of an image stabilization function, are applicable to a camera of either of the above electronic image stabilization types.

The measurement method according to embodiment 1 mainly uses a still image as an evaluation target. As a matter of course, since a moving image is collection of still images, also a moving image can be evaluated by evaluating individual still images composing the moving image by the measurement method according to embodiment 1.

The camera 400 to be measured according to embodiment 1 is a camera having an optical image stabilization function. However, the measurement method according to embodiment 1 is mainly used for measuring the performance of an image stabilization function of a camera having an electronic image stabilization function. Therefore, the camera 400 to be measured may be a camera having no optical image stabilization function as long as it has an electronic image stabilization function.

#### [1-3. Vibratory Apparatus]

FIG. 5 is a block diagram showing the configuration of the vibratory apparatus 100.

The vibratory controller 110 performs transmission and reception with the computer 200 via an input section 111. The vibratory controller 110 receives vibration data and the like from the computer 200, and feeds back the operation status of the vibratory apparatus 100 to the computer 200. Upon control of the vibratory apparatus 100, the vibratory controller 110 uses a memory 112 as a working memory. The vibration data transmitted from the computer 200 is stored into the memory 112. By referring to vibration data stored in the memory 112, the vibratory controller 110 controls a pitch direction motor driver 114 and a yaw direction motor driver 113.

The pitch direction motor driver 114 controls a pitch direction motor 141. The pitch direction vibrating mechanism 140 includes a mechanical component such as a rotational shaft, besides the pitch direction motor 141. In addition, the operation of the pitch direction motor 141 is fed back to the vibratory controller 110 via the pitch direction motor driver 114.

The yaw direction motor driver 113 controls a yaw direction motor 131. The yaw direction vibrating mechanism 130 includes a mechanical component such as a rotational shaft, besides the yaw direction motor 131. In addition, the operation of the yaw direction motor 131 is fed back to the vibratory controller 110 via the yaw direction motor driver 113.

The vibratory controller 110 controls the release button pressing mechanism 150 in accordance with an instruction from the computer 200.

#### [1-4. Vibration Data]

FIGS. 6 and 7 are waveform diagrams showing examples of vibration data sent from the computer 200 to the vibratory apparatus 100. The horizontal axis indicates time and the vertical axis indicates amplitude. FIG. 6 shows vibration data (for convenience, this vibration data is referred to as first vibration data) used for measuring a camera having a mass

smaller than a first mass. FIG. 7 shows vibration data (for convenience, this vibration data is referred to as second vibration data) used for measuring a camera having a mass larger than a second mass. The second mass is equal to or larger than the first mass. In each of FIGS. 6 and 7, vibration data in the yaw direction and vibration data in the pitch direction are both indicated.

In the measurement method of embodiment 1, when the mass of the camera 400 to be measured is smaller than the first mass, the first vibration data shown in FIG. 6 is selected, and meanwhile, when the mass of the camera 400 to be measured is larger than the second mass, the second vibration data shown in FIG. 7 is selected. In essence, in accordance with the mass of the camera 400 to be measured, one of several kinds of vibration data is selected. Then, the vibratory table 120 of the vibratory apparatus 100 is vibrated in accordance with the selected vibration data. Next, while the vibratory table 120 is being vibrated, the motion blur measurement chart 300 is imaged by the camera 400 to be measured to acquire an evaluation image, and a motion blur amount in the image is measured based on the acquired evaluation image.

As is obvious from FIGS. 6 and 7, the magnitude of the amplitude in a low frequency region normalized by the magnitude of the amplitude in a high frequency region in the first vibration data shown in FIG. 6 is larger than that in the second vibration data shown in FIG. 7. This is to take into consideration the fact that, in the case of taking an image with a light camera, a camera shake component with a low frequency becomes large because the camera is light and a photographer usually holds a camera with the eyes away from a back-side monitor upon taking an image. On the other hand, in the case of a heavy camera, in the first place, camera shake of a low frequency hardly occurs because the camera is heavy. In addition to this, in the case of a heavy camera, the fact that a photographer usually takes an image with the eyes close to a peep-type viewfinder is also taken into consideration.

Next, a procedure for generating the vibration data shown in FIGS. 6 and 7 will be described with reference to FIGS. 8 to 10. FIG. 8 is a flowchart showing a procedure for generating the vibration data. FIGS. 9 and 10 are conceptual diagrams showing the content of each processing step of the generation procedure.

First, measured data of a vibration waveform (camera shake waveform) applied to a camera due to camera shake at the time of imaging is acquired (S510). For example, a gyro sensor is attached on the camera, and then a photographer actually performs an imaging operation. Specifically, a photographer performs a pressing operation for a release button, holding the camera with the hand. Then, from the output of the gyro sensor at the time of imaging, measured data of vibration waveforms in the yaw direction and the pitch direction is acquired. At this time, the output of the gyro sensor is an angular velocity of the vibration waveform applied to the camera. Therefore, by integrating the angular velocity, a vibration waveform of the camera converted into angle can be acquired. Here, the time of imaging is a certain period including a release timing.

The purpose of acquisition of measured data of a camera shake waveform is to obtain data as a base for generating the first vibration data or the second vibration data. Therefore, it is desirable to acquire data based on as many photographers as possible and as many imaging scenes as possible.

Next, the measured data of the camera shake waveform in each of the yaw direction and the pitch direction is converted into frequency-amplitude data (S520). This conversion is performed by Fourier transform.

Next, the data in the yaw direction and the pitch direction after Fourier transform is divided into frequency component data (S530). For example, if frequencies are divided into bands at intervals of 1 Hz by Fourier transform, the first amplitude data  $A_n$  indicates an amplitude component in a frequency band of  $1\text{ Hz} \pm 0.5\text{ Hz}$ , and  $A_{2n}$  indicates an amplitude component of  $2\text{ Hz} \pm 0.5\text{ Hz}$ . Since the frequency band of camera shake is about 20 Hz at the highest, the data may be extracted up to that frequency. The processing of steps S520 and S530 is performed for all the pieces of measured data of the camera shake waveforms that have been acquired.

Next, based on all the pieces of yaw direction data processed by the steps up to S530, the average value of amplitude data is calculated for each frequency component data to obtain  $A_{\text{ave}nY}$ ,  $A_{\text{ave}2nY}$ , etc. (S540). Also for the pitch direction,  $A_{\text{ave}nP}$ ,  $A_{\text{ave}2nP}$ , etc. are calculated in the same manner (S540).

Next, inverse Fourier transform is performed for  $A_{\text{ave}nY}$ ,  $A_{\text{ave}2nY}$ , etc. which are the average values of the amplitude data of respective frequency component data for the yaw direction, thereby calculating vibration waveforms  $W_nY$ ,  $W_{2nY}$ , etc. in respective specific bands for the yaw direction (S550). Also for the pitch direction, vibration waveforms  $W_nP$ ,  $W_{2nP}$ , etc. are calculated in the same manner (S550).

Finally, the vibration waveforms  $W_nY$ ,  $W_{2nY}$ , etc. in the respective specific bands for the yaw direction are summed to generate a camera shake model waveform  $WY_{\text{model}}$  for the yaw direction (S560). Upon summing the vibration waveforms  $W_nY$ ,  $W_{2nY}$ , etc. in the respective specific bands, they are summed with their phases being shifted randomly. Also for the pitch direction, a camera shake model waveform  $WP_{\text{model}}$  is generated in the same manner (S560). Upon summing the vibration waveforms in the respective specific bands for the pitch direction, the same phase amounts as those used in the shifting for the yaw direction may be used, or other phase amounts may be used. Vibration data indicating these model waveforms is the first vibration data or the second vibration data.

Thus, since the first vibration data and the second vibration data are obtained by performing statistic processing for measured data about a vibration, vibration data simulating a real vibration can be obtained.

#### [1-5. Configuration of Computer]

FIG. 11 is a block diagram showing the configuration of the computer 200.

A CPU 210 controls a monitor 230, a hard disk 240, a memory 250, a first communication section 260, and a second communication section 270 in accordance with an instruction from a keyboard 220. The first communication section 260 is connected to the camera 400 to be measured and performs transmission and reception of data with the camera 400 to be measured. The second communication section 270 is connected to the vibratory apparatus 100 and performs transmission and reception of data with the vibratory apparatus 100. The first communication section 260 and the second communication section 270 may be a wired connection unit such as a USB or a wireless connection unit, for example.

The CPU 210 may be configured to acquire information about the settings of the camera 400 to be measured such as the focal length and the shutter speed value, from the camera 400 to be measured via the first communication section 260. In addition, the CPU 210 may be configured to acquire image data from the camera 400 to be measured via the first communication section 260. In addition, the CPU 210 may be configured to transmit a signal indicating a shutter release instruction to the camera 400 to be measured via the first communication section 260.

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The hard disk **240** stores two kinds of vibration data shown in FIGS. **6** and **7**. The hard disk **240** stores software such as a motion blur measurement software **500** and an evaluation value calculation software **600** described later. Such software is realized as a computer program. A computer program indicating such software may be stored in an optical disc and be installed into the computer **200** from the optical disc, or a computer program indicating such software may be stored into the hard disk **240** via a network and then installed into the computer **200**. The software stored into the hard disk **240** is loaded onto the memory **250** as necessary, to be executed by the CPU **210**. The computer program for realizing such software can be stored into a storage medium such as a memory card, a magnetic disk, or a magnetic tape, besides an optical disc or a hard disk.

The CPU **210** transmits vibration data stored in the hard disk **240** to the vibratory apparatus **100** via the second communication section **270**. In addition, the CPU **210** receives a signal indicating the operation state of the vibratory apparatus **100** from the vibratory apparatus **100** via the second communication section **270**.

The CPU **210** uses the memory **250** as a working memory. The monitor **230** displays a calculation result and the like obtained by the CPU **210**.

[1-6. Configurations of Motion Blur Measurement Software and Evaluation Value Calculation Software]

FIG. **12** is a block diagram showing the configuration of the motion blur measurement software **500**. The motion blur measurement software **500** is software for measuring a bokeh offset amount and a measured comprehensive bokeh amount from an image obtained by imaging the motion blur measurement chart **300**. Here, the bokeh offset amount is a bokeh amount of a shot image due to a factor other than camera shake, and specifically, is a numerical value that is unique to each device and that depends on the optical performance, effective pixels, image processing, and the like of the camera **400** to be measured. In addition, the measured comprehensive bokeh amount is a measured value of a bokeh amount of an image taken with the image stabilization function being ON, when the camera **400** to be measured is vibrated based on a vibration waveform (waveform indicated by the vibration data). A task management section **510** performs overall task management. The processing contents of blocks from an image signal acquiring section **520** to a multiplication processing section **590** will be described later, together with the description of a camera shake measurement procedure (FIG. **17**) which will be also described later.

FIG. **13** is a block diagram showing the configuration of the evaluation value calculation software **600**. The evaluation value calculation software **600** is software for calculating an evaluation value indicating the performance of an image stabilization function of the camera **400** to be measured. A task management section **610** performs overall task management. A bokeh offset amount measurement section **622** and a measured comprehensive bokeh amount measurement section **642** are blocks incorporating the motion blur measurement software **500** or using the motion blur measurement software **500**. That is, the motion blur measurement software **500** can be also regarded as subroutine software of the evaluation value calculation software **600**. The processing contents of blocks from a static state image acquiring section **621** to an image stabilization performance evaluation value calculation section **650** will be described later, together with the description of an evaluation value calculation procedure (FIG. **19**) which will be also described later.

## 2. Evaluation Procedure

An evaluation procedure for measuring the performance of the image stabilization function of the camera **400** to be

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measured by using the measurement system configured as described above, will be described with reference to FIG. **14**.

The measurement method according to embodiment **1** mainly measures the performance of an image stabilization function of a camera having an electronic image stabilization function. In embodiment **1**, it is assumed that the state where the image stabilization function is ON is the state where the optical image stabilization is OFF and the electronic image stabilization is ON.

The camera **400** to be measured is placed on the vibratory table **120**, and then the camera **400** to be measured takes an image of the motion blur measurement chart **300** without shaking the vibratory table **120**, thereby generating a static state image (S**100**). Next, the camera **400** to be measured is fixed on the vibratory table **120**, and then the camera **400** to be measured takes an image of the motion blur measurement chart **300** with the vibratory table **120** being vibrated, thereby generating a vibrated state image (S**200**). Here, both the static state image and the vibrated state image are still images. Finally, based on the static state image and the vibrated state image that have been taken and the setting values of the camera **400** to be measured, the computer **200** measures or calculates a theoretical motion blur amount, a bokeh offset amount, an estimated comprehensive bokeh amount, a measured comprehensive bokeh amount, a reference motion blur amount, a measured motion blur amount, a reference shutter speed value, a measured shutter speed value, a reference noise level, an evaluated noise level, and a degree of influence on image quality. Then, the computer **200** calculates an evaluation value indicating the performance of the image stabilization function of the camera **400** to be measured.

Here, the theoretical motion blur amount is a theoretical value of a motion blur amount that can be measured from an image that would be obtained with the image stabilization function being OFF (in the case of a camera not having OFF setting, assumed to be OFF) when the camera **400** to be measured is vibrated based on a vibration waveform.

In addition, the estimated comprehensive bokeh amount is a theoretical estimated value of a bokeh amount of an image that would be obtained with the image stabilization function being OFF (in the case of a camera not having OFF setting, assumed to be OFF) when the camera **400** to be measured is vibrated based on a vibration waveform. The estimated comprehensive bokeh amount is represented as the square root of the sum of square of the bokeh offset amount and square of the theoretical motion blur amount.

In addition, the reference motion blur amount is a numerical value that is a reference for calculating the image stabilization performance. The reference motion blur amount is a numerical value obtained by subtracting the bokeh offset amount from the estimated comprehensive bokeh amount.

In addition, the measured motion blur amount is a numerical value indicating the remaining camera shake that has not been corrected eventually when the image stabilization function of the camera **400** to be measured is ON. The measured motion blur amount is obtained by subtracting the bokeh offset amount from the measured comprehensive bokeh amount.

Further, the reference noise level and the evaluated noise level are values defined by a variance of brightness of the gray area **304** on the blur measurement chart **300**, and are used for evaluating the performance of the electronic image stabilization function of the camera **400** to be measured.

### [2-1. Static State Imaging Procedure]

The details of a static state imaging procedure (S**100**) will be described with reference to a flowchart shown in FIG. **15**.

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First, the camera **400** to be measured is placed on the vibratory table **120** (S101). In the static state imaging, since the vibratory table **120** is not vibrated upon imaging, the camera **400** to be measured may not necessarily be fixed on the vibratory table **120**. However, it is preferable that the camera **400** to be measured is fixed on the vibratory table **120** in order to ensure the stability of measurement and working continuity to vibrated state imaging described later. It is preferable that the distance (imaging distance) from the camera **400** to be measured to the motion blur measurement chart **300** is set such that the area defined by the imaging area marker **303** shown in FIG. 2 is the imaging area.

Next, the imaging conditions of the camera **400** to be measured such as a focal length and an image stabilization mode are set (S102). In the static state imaging, it is desirable that the electronic image stabilization function is OFF. However, in some cameras, the electronic image stabilization function cannot be freely turned off. In such a case, since the camera is static upon imaging, the imaging may be performed with the image stabilization function being ON under the assumption that the image stabilization function is not exerted.

Next, the shutter speed value of the camera **400** to be measured is set (S103). For example, an initial shutter speed value is set to about 1/focal length (35 mm film equivalent). In both of static state imaging (S200) and vibrated state imaging (S300), a plurality of images need to be taken for each of a plurality of shutter speeds. Accordingly, after a plurality of images are taken with the same shutter speed value, the shutter speed value is sequentially set again so as to be slowed down by up to one stop, and thus the same imaging is repeated until the shutter speed value reaches a necessary and sufficient value.

Next, the release button pressing mechanism **150** is driven to cause the camera **400** to be measured to take an image (S104). The controller **440** stores the shot image into the memory card **451**, in a form of image file having a header added thereto, the header storing imaging condition information such as information indicating the focal length, the shutter speed value, and the image stabilization mode. Thus, the shot image can be stored so as to be associated with the imaging condition.

Next, the CPU **210** determines whether or not a predetermined number of images have been taken for all of the intended shutter speed values (S105), and then if such imaging has been completed (Yes in S105), ends the static state imaging procedure.

On the other hand, if such imaging has not been completed yet (No in S105), the CPU **210** determines whether or not to change the shutter speed value (S106). This determination is performed based on whether or not the predetermined number of images have been taken for the shutter speed value that is currently set. If the shutter speed value is not changed (No in S106), the process returns to step S104 to perform again the static state imaging with the shutter speed value that is currently set. If the shutter speed value is changed (Yes in S106), the process returns to step S103 to change the shutter speed value and then the static state imaging is performed again.

As a result of the above static state imaging procedure, the memory card **451** stores the predetermined number of static state images for each of the plurality of shutter speed values. Here, it is preferable that the predetermined number is about 10 or more for each shutter speed.

#### [2-2. Vibrated State Imaging Procedure]

Next, the details of the vibrated state imaging procedure (S200) will be described with reference to a flowchart shown in FIG. 16.

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First, the camera **400** to be measured is fixed on the vibratory table **120** (S201). If the camera **400** to be measured has been fixed on the vibratory table **120** in step S101 in the static state imaging, the static state imaging can be directly shifted to the vibrated state imaging in the same state. As in the static state imaging, it is preferable that the distance (imaging distance) from the camera **400** to be measured to the motion blur measurement chart **300** is set such that the area defined by the imaging area marker **303** shown in FIG. 2 is the imaging area.

Next, the operation condition of the vibratory table **120** is set (S202). An evaluator selects the first vibration data shown in FIG. 6 or the second vibration data shown in FIG. 7 in accordance with the mass of the camera **400** to be measured. Specifically, for example, if the mass of the camera **400** to be measured is smaller than the first mass, the first vibration data is selected from among a plurality of pieces of vibration data, and if the mass of the camera **400** to be measured is larger than the second mass, the second vibration data is selected from among the plurality of pieces of vibration data. The vibration data selected by the evaluator is given to the vibratory controller **110** from the computer **200**.

Next, the imaging conditions of the camera **400** to be measured are set (S203). In the vibrated state imaging, the electronic image stabilization function is set to ON. The focal length of the camera **400** to be measured is set at the same value as in the static state imaging.

Next, based on the vibration data selected by the evaluator, the vibratory table **120** is vibrated (S204).

Next, the shutter speed value of the camera **400** to be measured is set (S205). For example, the way of setting an initial shutter speed value and changing the shutter speed value thereafter is the same as in the static state imaging.

Next, the release button pressing mechanism **150** is driven to cause the camera **400** to be measured to take an image (S206). The way of storing the shot image into the memory card **451**, and the like are the same as in the static state imaging.

Next, the CPU **210** determines whether or not a predetermined number of images have been taken for all of the intended shutter speed values (S207), and then if such imaging has been completed (Yes in S207), ends the vibrated state imaging procedure.

On the other hand, if such imaging has not been completed yet (No in S207), the CPU **210** determines whether or not to change the shutter speed value (S208). This determination is performed based on whether or not the predetermined number of images have been taken for the shutter speed value that is currently set. If the shutter speed value is not changed (No in S208), the process returns to step S206 to perform again the vibrated state imaging with the shutter speed value that is currently set. If the shutter speed value is changed (Yes in S208), the process returns to step S205 to change the shutter speed value and then the vibrated state imaging is performed again.

As a result of the above vibrated state imaging procedure, the memory card **451** stores the predetermined number of vibrated state images for each of the plurality of shutter speed values. Here, it is preferable that the predetermined number is about 200 or more for each shutter speed. The reason for taking many images is that there are variations in the motion blur amounts of the images and therefore it is necessary to perform statistic processing such as average value calculation about the motion blur amounts of the images.

#### [2-3-1. Camera Shake Measurement Procedure]

Before the description of a calculation procedure for an evaluation value indicating the performance of the image stabilization function of the camera **400** to be measured, a

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camera shake measurement procedure will be described with reference to FIG. 17. It is noted that the camera shake measurement procedure is executed as a part of the evaluation value calculation procedure. In addition, the camera shake measurement procedure is executed by the motion blur measurement software shown in FIG. 12, using hardware resources of the computer 200. Therefore, FIG. 12 will be referred to as necessary in the description.

First, an image signal acquiring section 520 causes the computer 200 to acquire an image signal for evaluation (S401). More specifically, the CPU 210 acquires an image signal stored in the memory card 451 by connecting the memory card 451 to the computer 200 or from the camera 400 to be measured via the first communication section 260, and then stores the image signal into the hard disk 240 or the memory 250. The image signal to be acquired may be an image signal indicating a static state image or an image signal indicating a vibrated state image.

Next, a level value acquiring section 530 causes the computer 200 to acquire, from the shot image signal, the level value of an image signal of the black area 301 and the level value of an image signal of the white area 302 shown in FIG. 2 (S402). Here, the level of an image signal refers to a predetermined physical quantity about the image signal, e.g., the brightness of the image signal.

Next, a normalizing section 540 causes the computer 200 to normalize the level value of the shot image signal with reference to a specific range (S403). For example, in the case where "10" is acquired as the level value of the image signal of the black area 301, "245" is acquired as the level value of the image signal of the white area 302, and the normalization is performed in a range of "0 to 255", the level value of the image signal of the black area 301 is set at "0" (hereinafter, for convenience, referred to as a first level value), and the level value of the image signal of the white area 302 is set at "255" (hereinafter, for convenience, referred to as a second level value).

FIG. 18 is a graph showing variation in the normalized level values at the boundary between the black area 301 and the white area 302. In FIG. 18, the horizontal axis indicates the number of a pixel formed on the CCD image sensor 420. The normalizing section 540 causes the computer 200 to normalize all the level values based on measured values at a pixel P1 in the black area 301 and a pixel P6 in the white area 302, for example.

Next, a difference calculation section 550 causes the computer 200 to calculate the difference between the level value of the image signal of the black area 301 and the level value of the image signal of the white area 302 (S404). In this case, these level values have been normalized in a range of "0 to 255" and therefore naturally, the difference becomes 255. This step S404 has a significance mainly when camera shake measurement is performed without normalization of the level values.

Next, a corrected level value calculation section 560 causes the computer 200 to calculate a first corrected level value by adding X % of the calculated difference to the first level value, and to calculate a second corrected level value by subtracting Y % of the calculated difference from the second level value. Specifically, if X % is 10% and Y % is 10%, the first corrected level value is "25.5" and the second corrected level value "229.5".

Next, a corrected level position specifying section 570 causes the computer 200 to specify a pixel position where the level value is the first corrected level value, as a first corrected level position, and a pixel position where the level value is the second corrected level value, as a second corrected level

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position, at the boundary between the black area 301 and the white area 302. With reference to FIG. 18, a pixel P3 is the first corrected level position and a pixel P4 is the second corrected level position.

Next, a distance calculation section 580 causes the computer 200 to calculate the distance between the first corrected level position and the second corrected level position (S407). With reference to FIG. 18, a distance A is the calculated distance. The distance A is a distance converted in 35 mm film equivalent from the number of pixels between the pixel P3 and the pixel P4.

Finally, a multiplication processing section 590 multiplies the distance calculated in step S407 by  $100/(100-X-Y)$  (S408). With reference to FIG. 18, since X % and Y % are both 10%, the distance A is multiplied by 10/8. The value thus calculated corresponds to an estimated value of a distance B. The distance B is a distance converted in 35 mm film equivalent from the number of pixels between the pixel P2 and the pixel P5.

The reason for actually measuring the distance in a specific level range and then estimating a bokeh amount at the boundary between the black area 301 and the white area 302 based on the measured distance, is to exclude the influence of noise at the boundary (the vicinity of the pixel P2 in FIG. 18) between the black area 301 and the bokeh area or the boundary (the vicinity of the pixel P5 in FIG. 18) between the white area 302 and the bokeh area. This is because the influence of noise is particularly likely to appear in the vicinity of such boundaries.

#### [2-3-2. Evaluation Value Calculation Procedure]

With reference to FIG. 19, the calculation procedure for an evaluation value indicating the performance of the image stabilization function of the camera 400 to be measured, will be described. In the following description, FIGS. 20 to 23 will be referred to as necessary. These figures are characteristic graphs of a camera shake, in which the horizontal axis indicates a shutter speed value and the vertical axis indicates a camera shake. In addition, evaluation value calculation procedure is realized by the evaluation value calculation software shown in FIG. 13, using the hardware resources of the computer 200. Therefore, the description will be performed by referring to FIG. 13 as necessary.

First, a theoretical motion blur amount calculation section 631 causes the computer 200 to acquire the focal length set on the camera 400 to be measured, calculate a focal length in 35 mm film equivalent from the acquired focal length, and then calculate a theoretical motion blur amount by using the focal length in 35 mm film equivalent (S301). Regarding the acquisition of the focal length, a value inputted via the keyboard 220 by an evaluator may be accepted, a setting value may be received from the camera 400 to be measured, or the value may be read from the header of an image file. The theoretical motion blur amount is calculated based on the following expression.

$$\text{Theoretical motion blur amount } [\mu\text{m}] = \text{Focal Length in } 35 \text{ mm Film Equivalent } [\text{mm}] \times \tan \theta \times 1000$$

Here,  $\theta$  is referred to as an average vibration angle which is the average value, for each shutter speed, of camera shake angles that would occur when the camera is vibrated based on the vibration data. Since two kinds of vibration data are prepared as shown in FIGS. 6 and 7, at least two kinds of average vibration angles  $\theta$  are prepared, too. Since the average vibration angle  $\theta$  increases as the shutter speed value increases, the theoretical motion blur amount draws a trajectory schematically shown in FIG. 20.

Next, a static state image acquiring section **621** causes the computer **200** to acquire a plurality of static state images obtained by imaging the motion blur measurement chart **300** a plurality of times for each of the plurality of shutter speeds (**S302**). More specifically, the CPU **210** acquires the static state images stored in the memory card **451** by connecting the memory card **451** to the computer **200** or from the camera **400** to be measured via the first communication section **260**, and then stores the static state images into the hard disk **240** or the memory **250**.

Next, a bokeh offset amount measurement section **622** causes the computer **200** to measure, as a bokeh offset amount, a bokeh amount at the boundary between different color areas (in embodiment 1, between the black area **301** and the white area **302**) in the acquired static state images, for each of the plurality of shutter speeds (**S303**). The measurement of the bokeh offset amount is performed using the motion blur measurement software **500** shown in FIG. **12**, as described above.

Next, an estimated comprehensive bokeh amount calculation section **632** causes the computer **200** to calculate an estimated comprehensive bokeh amount for each of the plurality of shutter speeds by superimposing the measured bokeh offset amount onto the calculated theoretical motion blur amount for each of the plurality of shutter speeds (**S304**). The estimated comprehensive bokeh amount is represented as the square root of the sum of square of the theoretical motion blur amount and square of the bokeh offset amount, for example. As a result, the estimated comprehensive bokeh amount draws a trajectory schematically shown in FIG. **21**. By superimposing the bokeh offset amount onto the theoretical motion blur amount, as shown in FIG. **21**, as well as increase in the value of the estimated comprehensive bokeh amount, the change rate of the slope of the tangent of the curve changes. This is due to the influence of the bokeh offset amount, that is, this means that the influence of a bokeh of an image intrinsic to the camera **400** to be measured is incorporated into the present evaluation value calculation procedure. More simply, in the case of a camera intrinsically having a small bokeh amount, the curve of the estimated comprehensive bokeh amount is close to the curve of the theoretical motion blur amount, and on the other hand, in the case of a camera intrinsically having a large bokeh amount, the curve of the estimated comprehensive bokeh amount is far from the curve of the theoretical motion blur amount, and also, the change rate of the slope of the tangent thereof is small.

Next, a vibrated state image acquiring section **641** causes the computer **200** to acquire a plurality of vibrated state images obtained by imaging the motion blur measurement chart **300** a plurality of times for each of the plurality of shutter speeds (**S305**). More specifically, the CPU **210** acquires the vibrated state images stored in the memory card **451** by connecting the memory card **451** to the computer **200** or from the camera **400** to be measured via the first communication section **260**, and stores the vibrated state images into the hard disk **240** or the memory **250**.

Next, a measured comprehensive bokeh amount measurement section **642** causes the computer **200** to measure, as a measured comprehensive bokeh amount, a bokeh amount at the boundary between different color areas in the acquired vibrated state images, for each of the plurality of shutter speeds (**S306**). The measurement of the measured comprehensive bokeh amount is performed using the motion blur measurement software **500** shown in FIG. **12**, as described above. The measured comprehensive bokeh amount is measured as a bokeh amount in 35 mm film equivalent. As a result,

the measured comprehensive bokeh amount draws a trajectory schematically shown in FIG. **22**.

Next, a reference motion blur amount calculation section **633** causes the computer **200** to calculate a reference motion blur amount for each of the plurality of shutter speed values by subtracting the measured bokeh offset amount from the calculated estimated comprehensive bokeh amount (**S307**).

Next, a measured motion blur amount calculation section **643** causes the computer **200** to calculate a measured motion blur amount for each of the plurality of shutter speed values by subtracting the measured bokeh offset amount from the measured comprehensive bokeh amount (**S308**). At this time, if the measured motion blur amount becomes a negative value, the measured motion blur amount is made to be zero. As a result, the reference motion blur amount and the measured motion blur amount draw trajectories schematically shown in FIG. **23**.

Next, a reference shutter speed value calculation section **634** causes the computer **200** to calculate a shutter speed value that causes a specific motion blur amount, as a reference shutter speed value, by using the plurality of reference motion blur amounts that have been calculated (**S309**). The specific motion blur amount is, for convenience, referred to as a determination level for motion blur suppression performance. In FIG. **23**, a shutter speed value indicated by "SS\_OFF" is the reference shutter speed value.

Next, a reference noise level measurement section **635** extracts, from among the plurality of static state images acquired in step **S302**, a static state image taken at the reference shutter speed value calculated in step **S309**. Although in step **S302** a plurality of static state images have been taken at the same shutter speed value, the number of static state images to be extracted may be any number from one to all of the taken images. However, the larger the number is, the more the measurement variation is reduced, which results in improved evaluation accuracy. Subsequently, the reference noise level measurement section **635** calculates a variance of brightness of the gray area **304** in the extracted static state image (**S310**). If a plurality of static state images have been extracted, the reference noise level measurement section **635** calculates a variance of brightness of each static state image, and calculates an average variance of brightness over the static state images. The variance of brightness calculated by the reference noise level measurement section **635** is referred to as a reference noise level.

Next, a measured shutter speed value calculation section **644** causes the computer **200** to calculate a shutter speed value that causes the specific motion blur amount, as a measured shutter speed value, by using the plurality of measured motion blur amounts that have been calculated (**S311**). In FIG. **23**, a shutter speed value indicated by "SS\_ON" is the measured shutter speed value.

Next, an evaluated noise level measurement section **645** extracts, from among the plurality of vibrated state images obtained in step **S305**, a vibrated state image taken at the measured shutter speed value calculated in step **S311**. Although in step **S305** a plurality of vibrated state images have been taken at the same shutter speed value, the number of vibrated state images to be extracted may be any number from one to all of the taken images. However, the larger the number is, the more the measurement variation is reduced, which results in improved evaluation accuracy. Subsequently, the evaluated noise level measurement section **645** calculates a variance of brightness of the gray area **304** in the extracted vibrated state image (**S312**). If a plurality of vibrated state images have been extracted, the evaluated noise level measurement section **645** calculates a variance of brightness of

each vibrated state image, and calculates an average variance of brightness over the vibrated state images. The variance of brightness calculated by the evaluated noise level measurement section 645 is referred to as an evaluated noise level.

Next, an image quality influence calculation section 646 calculates a ratio of the evaluated noise level to the reference noise level. That is, the image quality influence calculation section 646 calculates a common logarithm of evaluated noise level/reference noise level and multiplies the common logarithm by 10 to obtain a value (dB). At this time, the image quality influence calculation section 646 calculates a second evaluation value (image quality influence degree  $\beta$ ) indicating the degree of influence on image quality. The image quality influence calculation section 646, for example, regards 3 dB as one stop, and calculates a stop number of shutter speed corresponding to the calculated value (dB) as the second evaluation value (S313).

Finally, an image stabilization performance evaluation value calculation section 650 causes the computer 200 to calculate a first evaluation value (motion blur suppression performance  $\alpha$ ) of the image stabilization function of the camera 400 to be measured for the focal length at which the imaging has been performed, by using the reference shutter speed value and the measured shutter speed value. In FIG. 23, a stop number of shutter speed between "SS\_OFF" and "SS\_ON" corresponds to the first evaluation value (motion blur suppression performance  $\alpha$ ). Subsequently, the image stabilization performance evaluation value calculation section 650 subtracts the second evaluation value (image quality influence degree  $\beta$ ) calculated in step S313 from the first evaluation value (motion blur suppression performance  $\alpha$ ) (S314). The result of the subtraction is the final evaluation value for the image stabilization performance of the camera 400 to be measured when the optical image stabilization function is OFF and the electronic image stabilization function is ON.

As described above, according to the evaluation method of embodiment 1, the image stabilization performance of the camera having the electronic image stabilization function can be calculated.

As a method of reducing influence of motion blur on a shot image, there is a method of reducing motion blur by simply making the shutter speed faster. However, in order to obtain appropriate exposure setting, instead of making the shutter speed faster, gain-up is needed, which may cause degradation of image quality of the shot image, such as noise increase. Thus, the method of simply making the shutter speed faster is not sufficient to achieve the image stabilization performance.

Also in the electronic image stabilization, since motion blur is corrected by combining a plurality of images each taken with a short exposure time, degradation of image quality such as noise increase might occur in the shot images. When only the optical image stabilization function is used without using the electronic image stabilization function, such degradation of image quality does not occur. Therefore, the degradation of image quality due to the electronic image stabilization is regarded to be equal to the degradation of image quality caused by simply making the shutter speed faster, and the degradation of image quality caused by the electronic image stabilization is converted into a difference in the number of stops in the case where the shutter speed is made faster, thereby calculating the image quality influence degree  $\beta$ . Then, the image quality influence degree  $\beta$  is subtracted from the motion blur suppression performance  $\alpha$  calculated based on the measured shutter speed and the reference shutter speed. Thus, in the electronic image stabilization, actual image stabilization performance can be obtained in

which influence of image quality degradation caused by inclusion of the shot images taken with the short exposure time is eliminated.

Accordingly, it is possible to realize an evaluation method by which the electronic image stabilization and the optical image stabilization can be fairly compared with each other.

In the procedure shown in embodiment 1, the influence of the bokeh offset amount is reflected in calculation of the estimated comprehensive bokeh amount and the reference motion blur amount. Hereinafter, the influence of the bokeh offset amount will be described in detail with reference to FIGS. 24 to 27.

In the following description, for facilitating the description, a camera A to be measured and a camera B to be measured having the same mass, the same focal length, and the same performance of the image stabilization function will be assumed. The bokeh offset amount of the camera A to be measured is smaller than that of the camera B to be measured. That is, the bokeh amount of an image intrinsic to the camera A to be measured is small, and the bokeh amount of an image intrinsic to the camera B to be measured is large. FIGS. 24 and 25 are characteristic diagrams of a motion blur amount showing the trajectories of the theoretical motion blur amount, the reference motion blur amount, and the measured motion blur amount. FIG. 24 is a characteristic diagram for the camera A to be measured, and FIG. 25 is a characteristic diagram for the camera B to be measured.

As shown in FIG. 24, since the bokeh offset amount of the camera A to be measured is small, the trajectory of the reference motion blur amount almost coincides with the trajectory of the theoretical motion blur amount. Therefore, even if the bokeh offset amount is not taken into consideration, that is, the theoretical motion blur amount is used as the trajectory of a motion blur amount obtained when the image stabilization function is OFF, the image stabilization performance corresponds to the stop number between the shutter speed value SS1 and the shutter speed value SS3. The image stabilization performance in the case of taking the bokeh offset amount into consideration corresponds to the stop number between the shutter speed value SS2 and the shutter speed value SS3. Therefore, the difference between both cases is slight as shown by the stop number between the shutter speed value SS1 and the shutter speed value SS2. That is, in the case of the camera A to be measured having a small bokeh offset amount, even if an evaluation value indicating the image stabilization performance is calculated without consideration of the bokeh offset amount, a significant problem does not occur so much.

On the other hand, in the case of the camera B to be measured having a large bokeh offset amount, if an evaluation value indicating the image stabilization performance is calculated without consideration of the bokeh offset amount, the calculated evaluation value deviates from the actual value, thus causing a significant problem. Hereinafter, this point will be described in detail.

First, since the camera A to be measured and the camera B to be measured have the same mass, the average vibration angles given in advance are the same. In addition, since their focal lengths are also the same, the theoretical motion blur amount of the camera A to be measured and the theoretical motion blur amount the camera B to be measured are the same. Therefore, as shown in FIG. 25, a shutter speed value at the intersection of the trajectory of the theoretical motion blur amount and the determination level for motion blur suppression performance becomes the shutter speed value SS1, in both cameras.

Next, since the bokeh offset amount of the camera B to be measured is large, as shown in FIG. 26, inclination of the

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trajectory of the measured comprehensive bokeh amount of the camera B to be measured is more gradual than that of the trajectory of the measured comprehensive bokeh amount of the camera A to be measured. The reason is as follows. That is, in the case of a camera having a large bokeh offset amount, in a region where the shutter speed value is small, the bokeh offset amount is more dominant to the measured comprehensive bokeh amount than a bokeh due to a camera shake, and meanwhile, in a region where the shutter speed value is large, the influence of a bokeh due to a camera shake becomes large, so that the difference in the measured comprehensive bokeh amount between the camera A to be measured and the camera B to be measured becomes small. Accordingly, by subtracting the bokeh offset amount from the measured comprehensive bokeh amount shown in FIG. 26, the measured motion blur amounts shown in FIG. 27 are obtained.

Here, if an evaluation value indicating the image stabilization performance is calculated from the stop number between the shutter speed value SS1 and the shutter speed value SS5 with reference to the theoretical motion blur amount without consideration of the bokeh offset amount, the camera B to be measured intrinsically having a large bokeh amount of an image is evaluated to have a higher performance of the image stabilization function even though the camera A to be measured and the camera B to be measured actually have the same performance of the image stabilization function. This is obviously inappropriate as an evaluation method.

Accordingly, in the present embodiment, the bokeh offset amount is taken into consideration upon calculation of an evaluation value indicating the performance of the image stabilization function. Specifically, upon calculation of the reference motion blur amount, the bokeh offset amount is superimposed onto the theoretical motion blur amount, thereby calculating the estimated comprehensive bokeh amount. Then, the bokeh offset amount is subtracted from the estimated comprehensive bokeh amount, thereby obtaining the reference motion blur amount. Thus, in the case of a camera having a large bokeh offset amount, the trajectory of the reference motion blur amount becomes away from the trajectory of the theoretical motion blur amount. That is, the shutter speed value (SS4) at the intersection of the trajectory of the reference motion blur amount and the determination level for motion blur suppression performance shown in FIG. 25 is larger than such a shutter speed value (SS2) in the case of the camera A to be measured shown in FIG. 24. Therefore, the stop number between the shutter speed value SS1 and the shutter speed value SS4 becomes larger than the stop number between the shutter speed value SS1 and the shutter speed value SS2. As a result, in the camera B to be measured, the evaluation value indicating the image stabilization performance becomes small which is obtained based on the stop number between the shutter speed value (SS4) at the intersection of the reference motion blur amount and the determination level for motion blur suppression function, and the shutter speed value (SS5) at the intersection of the measured motion blur amount and the determination level for motion blur suppression performance. Thus, the evaluation value becomes close to the evaluation value (the stop number between the shutter speed value SS2 and the shutter speed value SS3 shown in FIG. 24) obtained for the camera A to be measured, whereby a more appropriate evaluation value can be obtained.

To summarize, as is obvious from FIGS. 24 to 27, the larger the bokeh amount intrinsic to a camera to be measured is, the more gradual the trajectory of the measured motion blur amount is. Therefore, if an evaluation value indicating the performance of the image stabilization function is calculated

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based on the reference motion blur amount calculated without consideration of the bokeh offset amount, the result is that the larger the bokeh offset amount of a camera to be measured is, the higher the performance of the image stabilization function is. In order to avoid such a result, as in embodiment 1, the bokeh offset amount has been taken into consideration upon calculation of an evaluation value indicating the performance of the image stabilization function.

#### Embodiment 2

In embodiment 1, an example in which the image stabilization function of the camera 400 to be measured is in the state where optical image stabilization is OFF and electronic image stabilization is ON is explained. However, the evaluation method of the present disclosure is not limited thereto. That is, even if the image stabilization function of the camera 400 to be measured is in the state where optical image stabilization is ON and electronic image stabilization is ON, it is possible to evaluate the image stabilization performance in the same manner as the evaluation procedure described for embodiment 1.

#### Embodiment 3

In embodiment 1, the motion blur measurement software has been used for evaluation of the performance of the image stabilization function. Instead, for example, the motion blur measurement software may be incorporated into a camera.

By thus incorporating the motion blur measurement software, a bokeh amount of a shot image can be measured more accurately. This software can be utilized for a function of alerting a user that a shot image is blurred after the imaging or a function of correcting the bokeh of the shot image through image processing.

#### Embodiment 4

In embodiment 1, an evaluator has selected vibration data in accordance with the mass of the camera 400 to be measured. However, the computer 200 may select vibration data. In this case, the computer 200 functions as: a selection section for selecting one of a plurality of pieces of vibration data in accordance with the mass of the camera 400 to be measured; a vibration control section for shaking the vibratory table 120 of the vibratory apparatus 100 on which the camera 400 to be measured is fixed, in accordance with the selected vibration data; an acquiring section for acquiring an evaluation image taken and generated by the camera 400 to be measured while the vibratory table 120 is being vibrated; and a measurement section for measuring a motion blur amount of an image based on the acquired evaluation image. Thus, an evaluator's operation to select vibration data can be omitted.

Alternatively, a computer program including: a selection section for causing the computer 200 to select one of a plurality of pieces of vibration data in accordance with the mass of the camera 400 to be measured; a vibration control section for controlling the computer 200 so as to vibrate the vibratory table 120 of the vibratory apparatus 100 on which the camera 400 to be measured is fixed, in accordance with the selected vibration data; an acquiring section for causing the computer 200 to acquire an evaluation image taken and generated by the camera 400 to be measured while the vibratory table 120 is being vibrated; and a measurement section for causing the computer 200 to measure a motion blur amount of an image based on the acquired evaluation image, may be installed into the computer 200, whereby the measurement of motion blur

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amount of a camera may be realized. Such a computer program can be stored in a storage medium such as a memory card, an optical disc, a hard disk, or a magnetic tape. Thus, by realizing the measurement method for a motion blur amount of a camera as a computer program, it becomes possible to measure a motion blur amount of a camera, using a total-purpose computer.

In embodiment 4, the computer 200 acquires the mass of the camera 400 to be measured by any means. For example, an evaluator may input mass data of the camera 400 to be measured via the keyboard 220. Thus, an evaluator's operation to select vibration data can be omitted. Alternatively, a weight scale may be provided for the vibratory apparatus 100, and then mass data of the camera 400 to be measured may be acquired from the vibratory apparatus 100. Thus, the trouble for the evaluator to select vibration data or input the mass data can be saved.

## Other Embodiments

As embodiments of the present disclosure, the above embodiments 1 to 4 have been described. However, the present disclosure is not limited to embodiments 1 to 4, but may be used with modifications as appropriate. Then, other embodiments of the present disclosure will be collectively described in this section below.

In embodiment 1, the CCD image sensor 420 is adopted as an example of an image sensor. However, the present disclosure is not limited thereto. That is, other image sensors such as a CMOS image sensor, an NMOS image sensor, and the like are also applicable to the present disclosure.

In embodiment 1, the estimated comprehensive bokeh amount is calculated based on the theoretical motion blur amount and the bokeh offset amount, the bokeh offset amount is subtracted from each of the estimated comprehensive bokeh amount and the measured comprehensive bokeh amount, and then shutter speed values at the determination level for motion blur suppression performance are read, whereby a first evaluation value of an image stabilization function is calculated. However, the present disclosure is not limited thereto. For example, after the estimated comprehensive bokeh amount is calculated based on the theoretical motion blur amount and the bokeh offset amount, shutter speed values at a level obtained by adding the bokeh offset amount to the determination level for motion blur suppression performance may be read from the estimated comprehensive bokeh amount and the measured comprehensive bokeh amount, whereby a first evaluation value of an image stabilization function may be calculated. In essence, a first evaluation value of an image stabilization function of a camera may be calculated based on the theoretical motion blur amount, the bokeh offset amount, and the measured comprehensive bokeh amount.

In embodiment 1, the functions of the motion blur measurement software 500 and the evaluation value calculation software 600 have been realized by using hardware resources of the computer 200, but the present disclosure is not limited thereto. For example, the computer 200 may incorporate therein hardware such as wired logic for realizing the functions of the motion blur measurement software 500 and the evaluation value calculation software 600, thereby realizing the measurement of the motion blur amount and the calculation of the evaluation value. Alternatively, the functions of the motion blur measurement software 500 and the evaluation value calculation software 600 may be realized by using hardware resources of the vibratory apparatus 100. In essence, a measurement device capable of realizing the func-

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tions of the motion blur measurement software 500 and the evaluation value calculation software 600 may be provided in the measurement system shown in FIG. 1.

In embodiment 1, the evaluation system has been controlled by the computer 200, but the present disclosure is not limited thereto. For example, a camera to be measured may have such a control function. Specifically, the functions of the motion blur measurement software 500 and the evaluation value calculation software 600 may be provided with a camera to be measured, so that the camera to be measured by itself can calculate a first evaluation value of an image stabilization function based on a shot image. In addition, a camera to be measured may have vibration data and the like stored therein, so that the camera to be measured can control the vibratory apparatus 100.

In embodiment 1, in the camera shake measurement procedure (FIG. 17), the level value has been normalized (S403) to conduct the measurement flow of the motion blur amount, but the present disclosure is not limited thereto. For example, the measurement flow of the motion blur amount may be conducted without normalizing the level value.

In embodiment 1, the shutter speed value of the camera 400 to be measured has been set based on an instruction from the computer 200, but the present disclosure is not limited thereto. For example, the shutter speed value may be manually set by an evaluator before imaging of an evaluation image. Alternatively, in the case where the shutter speed value cannot be manually set, the shutter speed value automatically set by the camera 400 to be measured may be substantially set by adjustment of the amount of light radiated to the motion blur measurement chart 300.

While in embodiment 1 the total of the exposure times for the shot images used in the image combining process in the electronic image stabilization is defined as the total exposure time, the present disclosure is not limited thereto. A time period from when exposure of the first shot image is started to when exposure of the last shot image is ended may be defined as the total exposure time. In this case, in FIG. 4(3), although there is an image that is not used for the image combining process in the electronic image stabilization, the total exposure time is  $\frac{1}{2}$  sec. In addition, as a method of electronic image stabilization, when motion blur is corrected by image processing based on one image, the exposure time of the one image may be defined as the total exposure time.

In the reference noise level measurement in step S310 shown in FIG. 19 according to embodiment 1, if the extracted static state images do not include a static state image taken at a desired shutter speed, the following processes may be performed. That is, for example, the images may be taken again with the shutter speed being reset to the desired shutter speed. Alternatively, a reference noise level at the desired shutter speed may be estimated based on a static state image taken at a shutter speed faster than the desired shutter speed and a static state image taken at a shutter speed slower than the desired shutter speed, which shutter speeds sandwich the desired shutter speed. As a method for the estimation, for example, calculation of a weighted average of the shutter speeds sandwiching the desired shutter speed may be adopted.

In the evaluated noise level measurement in step S312 shown in FIG. 19 according to embodiment 1, if the extracted vibrated state images do not include a vibrated state image taken at a desired shutter speed, the following processes may be performed. That is, for example, the images may be taken again with the shutter speed being reset to the desired shutter speed. Alternatively, an evaluated noise level at the desired shutter speed may be estimated based on a vibrated state

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image taken at a shutter speed higher than the desired shutter speed and a vibrated state image taken at a shutter speed lower than the desired shutter speed, which shutter speeds sandwich the desired shutter speed. As a method for the estimation, for example, calculation of a weighted average of the shutter speeds sandwiching the desired shutter speed may be adopted.

In embodiment 1, the reference noise level measurement section 635 and the evaluated noise level measurement section 645 each perform, as a noise level calculation method, a method of calculating a variance of brightness of each shot image, and calculating an average variance over the shot images. However, the present disclosure is not limited thereto. For example, maximum, minimum, or median of a variance of brightness of each shot image may be calculated. For example, the maximum allows more strict evaluation of the image quality influence degree. The median allows evaluation with influence of variations in the noise levels of the shot images being eliminated.

In embodiment 1, the image quality influence calculation section 646, for example, regards 3 dB as one stop, and calculates a stop number of shutter speed corresponding to the calculated value (dB) as the second evaluation value. However, the present disclosure is not limited thereto. For example, a conversion formula for an image quality influence degree corresponding to one stop may be appropriately determined in accordance with the noise characteristics of the image sensor or the characteristics of signal processing in the camera.

In embodiment 1, the reference noise level measurement section 635 and the evaluated noise level measurement section 645 each may measure a noise level directly from an acquired image, or may measure a noise level after the acquired image is subjected to inverse  $\gamma$  correction.

In embodiment 1, the reference noise level measurement section 635 and the evaluated noise level measurement section 645 each calculate a variance of brightness of an acquired image. The present disclosure is not limited thereto. For example, the reference noise level measurement section 635 and the evaluated noise level measurement section 645 each may measure a standard deviation of brightness or an SNR (Signal Noise Ratio) of an acquired image.

In embodiment 1, the second evaluation value calculated by the image quality influence calculation section 646 may be limited to a non-negative value. For example, when only a shot vibrated state image is subjected to inappropriate noise reduction, the noise level of the shot vibrated state image is excessively reduced as compared to that of the shot static state image, and thereby the image quality influence degree might be calculated as a negative value. In this case, the image quality influence calculation section 646 cannot appropriately calculate the image quality influence degree, i.e., the second evaluation value. By limiting the second evaluation value to a non-negative value, a camera having the electronic image stabilization function can be evaluated more fairly. It is noted that measurement error occurs in the calculation of the second evaluation value. Therefore, even when the second evaluation value is negative, if the absolute value thereof is not larger than a predetermined value, the value may be rounded to zero to be used for evaluation.

In embodiment 1, in the static state imaging procedure (S100), if the camera 400 to be measured is set so as to intentionally increase the noise, an evaluator can intentionally increase the final evaluation value ( $\alpha - \beta$ ) of the image stabilization performance to be calculated, which hinders fair evaluation. Therefore, the setting of the camera 400 to be measured is desired to be the setting used for usual shooting,

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or the setting at the factory shipment. That is, the camera setting that does not allow the evaluator to intentionally increase the noise is more desirable.

In embodiment 1, the vibratory apparatus 100 vibrates the camera 400 to be measured by using the predetermined vibration data. However, the present disclosure is not limited thereto. For example, as a method of acquiring a vibrated state image, a person may take an object with a camera held by hands. However, it is needless to say that measurement with less variation can be achieved by vibrating the camera 400 to be measured with the vibratory apparatus 100 using the predetermined vibration data.

In embodiment 1, the result of subtraction of the second evaluation value (image quality influence degree  $\beta$ ) from the first evaluation value (motion blur suppression performance  $\alpha$ ) is the final evaluation value for the image stabilization performance of the camera 400 to be measured when the electronic image stabilization function is ON. However, the present disclosure is not limited thereto. That is, the first evaluation value and the second evaluation value may be independently regarded as the final evaluation result of the camera 400 to be measured. At this time, the first evaluation value serves as an index indicating the degree of suppression of blurring of an image of the camera 400 to be measured. The second evaluation value serves as an index indicating the image quality of the camera 400 to be measured. Thereby, general consumers can grasp the performance of the electronic image stabilization of the camera 400 to be measured, based on the two indices.

The measurement method of the present disclosure can be used for evaluating the performance of an image stabilization function of a camera. The camera may be of any type as long as the camera has an image stabilization function, including a consumer digital camera, a professional camera, a mobile phone with a camera function, or a camera of a smartphone, and the like.

In addition, the camera shake measurement method of the present disclosure can be used not only for evaluation of the performance of an image stabilization function of a camera but also for camera shake evaluation about other images. For example, the camera shake measurement method of the present disclosure can be used for camera shake evaluation about a shot image by providing the camera with such a system.

As presented above, embodiments have been described as examples of the technology according to the present disclosure. For this purpose, the accompanying drawings and the detailed description are provided.

Therefore, components in the accompanying drawings and the detail description may include not only components essential for solving problems, but also components that are provided to illustrate the above described technology and are not essential for solving problems. Therefore, such inessential components should not be readily construed as being essential based on the fact that such inessential components are shown in the accompanying drawings or mentioned in the detailed description.

Further, the above described embodiments have been described to exemplify the technology according to the present disclosure, and therefore, various modifications, replacements, additions, and omissions may be made within the scope of the claims and the scope of the equivalents thereof.

What is claimed is:

1. An evaluation method for evaluating the performance of an image stabilization function of an imaging apparatus, the evaluation method comprising:

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- a first imaging step of imaging an object, with the image stabilization function being ON and the imaging apparatus being vibrated;
  - a second imaging step of imaging the object, with the imaging apparatus being static;
  - a first calculation step of detecting a motion blur amount based on an image taken in the first imaging step, calculating a first shutter speed that causes the detected motion blur amount to be a predetermined amount, and calculating, based on the first shutter speed and a reference shutter speed obtained from information relating to the vibration given to the imaging apparatus, a first evaluation value indicating a difference between the first shutter speed and the reference shutter speed;
  - a second calculation step of calculating a second evaluation value indicating a difference in image quality between the image taken in the first imaging step and the image taken in the second imaging step; and
  - an evaluation step of calculating an evaluation value of the performance of the image stabilization function of the imaging apparatus, based on a result of subtraction of the second evaluation value from the first evaluation value.
2. The evaluation method according to claim 1, wherein in the second calculation step, the image quality is evaluated based on a variance of brightness of the image taken in the first imaging step and a variance of brightness of the image taken in the second imaging step, and the second evaluation value which indicates a difference in image quality between the image taken in the first imaging step and the image taken in the second imaging step is calculated.
  3. The evaluation method according to claim 1, wherein in the second calculation step, the difference in the image quality between the image taken in the first imaging step and the image taken in the second imaging step is converted into a difference in shutter speed, thereby calculating the second evaluation value.
  4. The evaluation method according to claim 2, wherein in the second calculation step, the difference in the image quality between the image taken in the first imaging step and the image taken in the second imaging step is converted into a difference in shutter speed, thereby calculating the second evaluation value.
  5. An evaluation apparatus, comprising:
    - a first acquisition section configured to acquire an image of an object which is taken with the image stabilization function being ON and the imaging apparatus being vibrated;
    - a second acquisition section configured to acquire an image of the object which is taken with the imaging apparatus being static;

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- a first evaluation value calculation section configured to detect a motion blur amount based on the image acquired by the first acquisition section, calculates a first shutter speed that causes the detected motion blur amount to be a predetermined amount, and calculate, based on the first shutter speed and a reference shutter speed obtained from information relating to the vibration given to the imaging apparatus, a first evaluation value indicating a difference between the first shutter speed and the reference shutter speed;
  - a second evaluation value calculation section configured to calculate a second evaluation value indicating a difference in image quality between the image acquired by the first acquisition section and the image acquired by the second acquisition section; and
  - a third evaluation value calculation section configured to calculate an evaluation value of the performance of the image stabilization function of the imaging apparatus, based on a result of subtraction of the second evaluation value from the first evaluation value.
6. A non-transitory computer-readable recording medium having stored therein a computer program, the computer program comprising:
    - a first acquisition section which causes the computer to acquire an image of an object which is taken with the image stabilization function being ON, and the imaging apparatus being vibrated;
    - a second acquisition section which causes the computer to acquire an image of the object which is taken with the imaging apparatus being static;
    - a first evaluation value calculation section which controls the computer to detect a motion blur amount based on the image acquired by the first acquisition section, calculates a first shutter speed that causes the detected motion blur amount to be a predetermined amount, and calculate, based on the first shutter speed and a reference shutter speed obtained from information relating to the vibration given to the imaging apparatus, a first evaluation value indicating a difference between the first shutter speed and the reference shutter speed;
    - a second evaluation value calculation section which causes the computer to calculate a second evaluation value indicating a difference in image quality between the image acquired by the first acquisition section and the image acquired by the second acquisition section; and
    - a third evaluation value calculation section which causes the computer to calculate an evaluation value of the performance of the image stabilization function of the imaging apparatus, based on a result of subtraction of the second evaluation value from the first evaluation value.

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